Developing healthcare workers' confidence in AI

Report 2 of 2

October 2022

NHS AI Lab & Health Education England

This report has been developed by Health Education England and the NHS AI Lab at the NHS Transformation Directorate.

Health Education England

Health Education England (HEE) exists for one reason only: to support the delivery of excellent healthcare and health improvement to the patients and public of England by ensuring that the workforce of today and tomorrow has the right numbers, skills, values and behaviours, at the right time and in the right place.

At any one-time HEE supports more than 160,000 students and trainees whilst working closely with partners across the NHS locally, regionally, and nationally on shared priorities.

In 2019, HEE were commissioned by the then Secretary of State to deliver the Topol Review recommendations looking at the impact of leading-edge digital technologies on the workforce. The Digital, Artificial Intelligence and Robotics Technologies in Education (DART-Ed) programme picks up from this in 2021 to explore the linkage between mature evidenced AI and its workforce impact and required training and education.

NHS AI Lab

The NHS AI Lab was set up to accelerate the safe, ethical and effective adoption of AI in health and social care. Its vision is that the UK will be world leading for the development and use of AI-driven technologies to improve people's health and wellbeing, delivering the most impactful technology to support our health and care system. The Lab creates an environment for collaboration and co-creation by bringing together programmes that address the barriers to developing and deploying AI in health and care. This will unlock the potential of AI to change the way healthcare is delivered, whilst ensuring we can determine the right guidance and regulations to protect patients and those in care.

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Contents

Glossary of terms

AHCS	Academy for Healthcare Science
AI	Artificial Intelligence
AphA	Association of professional healthcare Analysts
BCS	British Computer Society
CCIO	Chief Clinical information Officer
CHIME	College of Healthcare Information Management Executives
CIO	Chief Information Officer
CNIO	Chief Nursing Information Officer
CRDM	Clinical Reasoning and Decision Making
CSO	Clinical Safety Officer
DART-Ed	Digital, AI and Robotics Technologies in Education
DDaT	Digital, Data and Technology
FCI	Faculty of Clinical Informatics
FEDIP	Federation of Informatics Professionals
FPT	Flexible Portfolio Training
GMC	General Medical Council
HEE	Health Education England
HCPC	Health and Care Professions Council
HSST	Higher Specialist Scientist Training
ICS	Integrated Care System
IG	Information Governance
IT	Information Technology
ISDN	Informatics Skills Development Networks
MDT	Multi-Disciplinary Team
NHS	National Health Service
NMC	The Nursing and Midwifery Council
NSHCS	National School of Healthcare Science
PCN	Primary Care Network
PMO	Project Management Office
SIG	Special Interest Group
STP	Scientist Training Programme

Foreword

In 2019, in our letter to the United Kingdom Secretary of State for Health and Social Care, on behalf of the NHS's team review for *Preparing the healthcare workforce to deliver the digital future* (Topol Review), we projected how 'empowerment of individuals who will increasingly be generating their own health data with the help of algorithms to interpret that data; and a marked improvement in the speed, accuracy and scalability of medical data interpretation offered by artificial intelligence (AI)' would provide 'robust support for all types of clinicians' and 'will lead to an evolution of the patient doctor relationship'. The report made the important recommendation that 'education resources should be developed to educate and train all healthcare professionals in health data provenance, curation, integration and governance; ethics of AI and autonomous systems and tools; critical appraisal and interpretation of AI and robotics technologies'.

In response to this recommendation, I am pleased to see that Health Education England (HEE) have established the DART-Ed (Digital, AI and Robotics Technologies in Education) Programme, to address the challenges of developing, growing, and retaining a digitally literate workforce. This collaborative research from HEE and the NHS AI Lab represents a significant step forward in developing confidence in AI in the healthcare workforce. It has built on the recommendations to address the significant skill gaps in clinical informatics and data driven technologies, acknowledging the importance of professionalisation and accreditation of individuals working in these areas, and the need to develop flexible training pathways that allow joint clinical and technical training, as well as developing partnerships with industry and educational organisations.

In a previous report, factors which contribute to confidence in AI were outlined in an impressive framework, and this second report adds to the framework by describing the NHS workforce in terms of AI archetypes (Shapers, Drivers, Creators, Embedders, and Users) and providing recommendations on the knowledge and skill areas across these archetypes which can be vital to equipping the workforce to implement and use AI safely, effectively, and ethically.

I would like to commend the organisations involved for investing in this world leading research collaborative and thank everyone who has helped to build on the recommendations outlined in our review by contributing to this research output. Indeed, it is a model for other countries to adopt as we move forward with implementing AI in medical practice. I look forward to following the next steps to this work in the forthcoming project, 'Establishing healthcare workers' confidence in AI'.

Eric Topol MD
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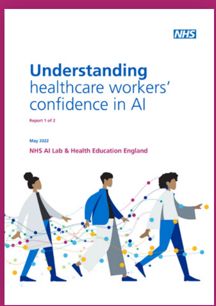
Executive Summary

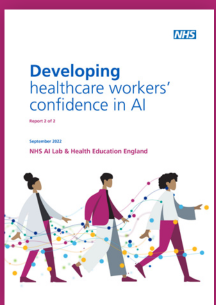
This research is a collaboration between the NHS AI Lab and Health Education England. Its primary aim is to inform the development of education and training to develop healthcare workers' confidence in artificial intelligence (AI).

The research follows the Topol Review (2019) recommendation to develop a healthcare workforce able and willing to use AI and robotics, and is part of Health Education England's Digital, AI and Robotics Technologies in Education (DART-Ed) programme to understand the impact of advances of these technologies on the workforce's education and training requirements. Supporting healthcare workers to feel confident in identifying when and how to use AI is a main objective of the NHS AI Lab, and a key component of its vision for the safe, effective, and ethical adoption of AI technologies across health and care.

This is the second of two reports in relation to this research.



The **first report**[1] outlined a conceptual framework for understanding what influences confidence in AI among healthcare workers.



This second report:

- identifies archetypes within the workforce based on AI-related roles and responsibilities
- determines educational and training needs based on these archetypes and the findings and conceptual framework of the first report
- presents suggested pathways to develop related education and training offerings.

Audiences for this report

At a strategic level, the report can inform how Health Education England, educational and training providers and educators of healthcare workers plan, resource, develop and deliver educational offerings to equip the workforce with necessary knowledge, skills and capabilities.

Educational and training providers include (but are not limited to) the NHS Digital Academy, Medical schools and other healthcare undergraduate and postgraduate programmes, Council of Deans, National Association of Clinical Tutors, Royal Societies and colleges, and other private and voluntary sector providers.

More specifically, the report can assist these entities and individuals to develop specific curricula and content for their educational and training offerings through the areas of knowledge, skills and capabilities listed in **Chapter 3** and **Appendix A**.

The research involved a review of academic literature and semi-structured interviews exploring experiences of developing and using AI technologies in healthcare settings. Interviewees included healthcare workers in primary and hospital care settings; industry innovators; representatives of related regulatory and arm's length bodies; and academics who work at the intersection of AI, healthcare, education and clinical confidence.

Workforce archetypes

Interviewees for this research described various roles and responsibilities that relate to how AI technologies are developed, implemented and used in health settings. Following an analysis of these descriptions, this report presents five groupings, referred to as archetypes, as detailed in **Figure A**.

The five archetypes include Shapers, Drivers, Creators, Embedders and Users. Individuals acting as each archetype will have different knowledge and skills requirements to confidently develop, implement or use AI technologies, and hence specific educational needs.

The archetypes do not necessarily align with traditional professional groups (for example, doctors, nurses, allied health professionals), specialisms or levels of seniority, but depend solely on an individuals' role in the development, implementation and use of AI technologies.

Although most healthcare workers will have responsibilities associated with one archetype, the archetypes are not mutually exclusive. For example, a clinician could be involved in co-creating AI technologies (as a Creator), validating AI technologies procured for use within their setting (as an Embedder) and undertaking clinical work using AI technologies (as a User). These responsibilities may involve single or multiple projects.

Figure A: AI workforce archetypes

Shaper

Set the direction for AI policy and governance at a national level

Example responsibilities

- Decide on AI policies within healthcare at a national level
- Author and enforce regulation for AI technologies, for professionals creating and using AI and for healthcare settings implementing AI
- Create guidelines for the creation, procurement, deployment and use of AI
- Guide training of healthcare professionals

Driver

Champion and lead AI development and deployment at a regional/local level

Example responsibilities

- Set the vision for digital and AI transformation at a regional/local level
- Champion AI technologies, by communicating the value and benefits, as a recognised and trusted leader
- Lead strategic decision-making related to AI procurement and deployment at a regional/local level
- Implement local AI governance infrastructure to ensure that AI is being deployed safely
- Promote funding and resource allocation for AI at a regional/local level
- Recruit and lead NHS AI multi-disciplinary teams (MDT)

Creator

Create AI technologies for use in healthcare settings

Example responsibilities

- Create AI algorithms independently or through collaboration with industry innovators and/or academia
- Test and validate AI algorithms during product development and subsequent releases
- Evaluate AI in terms of performance and clinical impact
- Set up systems for the ongoing monitoring of AI algorithms to assess for any model drift

Embedder

Implement, evaluate and monitor AI technologies deployed within healthcare settings

Example responsibilities

- Conduct technical implementation and systems integration
- Ensure that healthcare data used by AI technologies is managed safely and securely
- Establish and manage safety processes for reporting AI technology issues and back-up pathways for when products fail
- Participate in ongoing monitoring of AI technologies assessing for any model drift, including designing and performing algorithmic audits

User

Use AI technologies within healthcare settings

Example responsibilities

- Use AI within healthcare settings in accordance with guidelines
- Employ appropriate safety measures related to the use of AI
- Communicate with patients and the public about AI

Suggested educational approach

Educating healthcare workers to develop, implement and use AI effectively and safely is a multidimensional challenge, involving undergraduate education, postgraduate training, and lifelong learning. The challenge is to provide the right resources to the right people and build skills and capabilities across the healthcare workforce in the most efficient and effective way possible.

This challenge demands an approach to educating and training for AI that is flexible, including a mixture of widespread acquisition of awareness and knowledge whilst also supporting specialist skills and capabilities to deploy and maintain these technologies. This means providing a solid foundation for developing AI-related knowledge as well as personalised advanced educational elements to fit the needs of individuals in different roles and responsibilities (the workforce archetypes).

Based on these observations, **Figure B** illustrates the suggested approach to education and training for AI in healthcare.

The **foundational** AI education will aim to develop awareness and knowledge in healthcare workers. Education and training at this foundational level will need to be delivered both as an accessible education programme in a scalable format to existing staff and incorporated into educational programmes for future professionals.

Workers who may take up any of the archetype roles will require this foundational education prior to any advanced education offerings.

The broad aim of the **advanced** AI education will be to develop in-depth understanding of, and skills related to, the subject area. This will enable healthcare workers to lead different aspects of the deployment of AI technologies in health settings and advise others.

This report lists detailed educational requirements for knowledge, skills and capabilities mapped against the foundational, advanced and product-specific pathways, the workforce archetypes and the factors that influence confidence in AI. **Chapter 3** and **Appendix A** provide these details.

Figure B: Suggested education and training approach

1) As essential groundwork to AI education and training, continuation of the broader efforts to enable the adoption of change and innovation in healthcare settings, as well as efforts to advance **digital literacy, skills, and capabilities** within the workforce (such as the digital transformation pathways outlined in the NHS Long Term Plan[2], the Topol[3] and Goldacre[4] reviews, the plan for digital health and social care[5], and 'Data saves lives' strategy[11])

2) Development and provision of **general education and training for AI** through:

- **a) foundational** AI education across the whole healthcare workforce, including basic AI literacy and awareness of the limitations and risks of using AI technologies
- **b) advanced** AI education that is specific to the workforce archetypes, including development of skills and capabilities

3) Provision of **product-specific** training for users of **each AI technology** during its deployment

The wider context and workforce transformation

Interviewees for this research noted that the success of AI-related education and training will be dependent on wider requirements for transformation and change towards a digital-ready workforce.

These involve the development of novel team structures, the recruitment, training and retaining of individuals with specialist AI skills (including clinical informatics and digital, data and technology professionals), and new leadership roles that can support health settings to deploy AI technologies.

Workforce transformation, as defined by HEE, is a process to improve the recruitment, retainment, deployment, development and ongoing support of the healthcare workforce, to meet the growing and changing needs of local populations – ensuring high quality care for the patients of today and the future.

Workforce transformation efforts to support AI-related education and training can be grouped against the five enablers of the HEE Star framework[6], as illustrated in **Figure C**.

Specific considerations when developing Integrated Care System (ICS) workforce plans can include:

- establishment of AI multidisciplinary teams (MDTs)
- development of a plan to increase the digital, data and technical (DDaT) data family workforce to meet future demand. This can include new clinical informatics specialist roles, supported training opportunities, upskilling existing staff into technical roles and joint digital/clinical training opportunities for clinical staff. If deemed necessary, it could also include routes for external expertise to be brought into the healthcare sector
- creation of senior (non-managerial) technical roles with expert AI-related knowledge and skills
- expansion of professional digital leadership positions to lead AI development and deployment

Figure C: Workforce transformation to support AI-related education

Supply

- Establish clear job roles and career pathways for digital, data and technology specialists
- Expand the specialist, digital, data and technology (DDaT) data family professions and clinical informatics workforce through targeted recruitment, increased education and training opportunities, competitive renumeration and flexible equivalence pathways for those with skills from experience outside the NHS
- Support professionalisation and accreditation of the DDaT data family professions and clinical informatics workforce through recognised and trustworthy national bodies

Upskilling

- Maximise the potential of the workforce through recognised and accredited digital career and education pathways
- Support ongoing CPD (Continuing Professional Development) frameworks for development and validation of digital professionals
- Provide protected education time for digital skill development supported by flexible hybrid training pathways for digital specialist clinicians
- Provide equitable access to training and support, including special efforts to engage and support the digitally unengaged or unconvinced

New roles

- Identify gaps that may be filled by development or implementation of new roles

New ways of working

- Establish and support AI multi-disciplinary teams (MDTs) involving clinical and technical roles to lead the evaluation, deployment and product-specific user training for AI technologies. A diverse team and a flat organisational structure should be encouraged to avoid hierarchy and minimise bias
- Through innovative placements and recruitment, promote an integrated workforce that creates new relationships and networks and a working environment that embraces intrapreneurship and collaboration

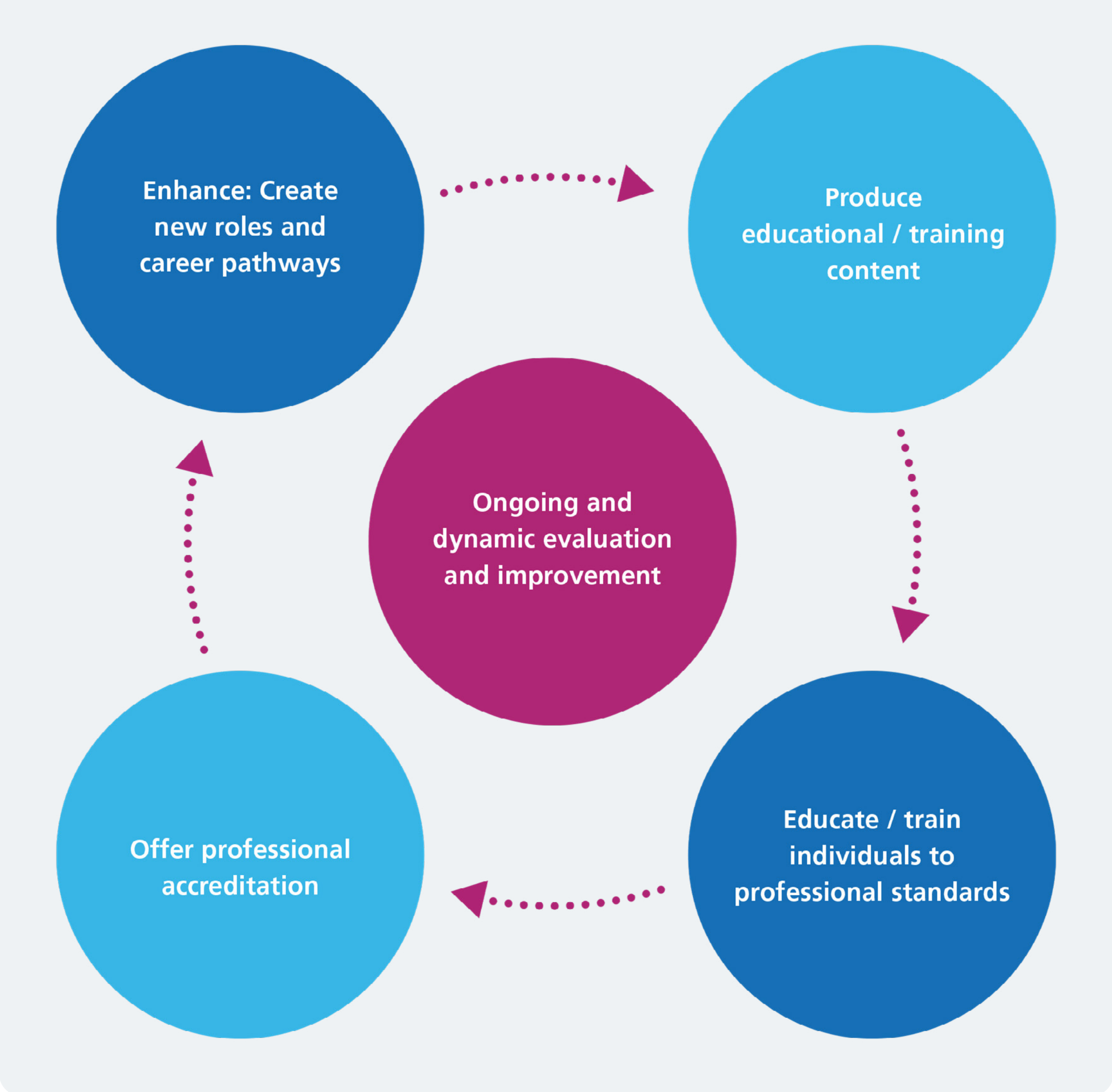
Leadership

- Develop a new cadre of digital leadership roles with recognition of the value of specialist skills at a senior level for individuals with DDaT data family and clinical informatics skills
- Set out clear training pathways and career trajectories to achieve a specific set of competencies required for digital leadership.

Developing and sustaining specialist AI-related skills will require the development of appropriate education, accreditation and career pathways as illustrated in **Figure D**. This should be supported by ongoing and dynamic evaluation and improvement of educational efforts, professional accreditation routes and career pathways.

Current initiatives that address aspects of this workforce development cycle include Health Education England establishing the Data Science Programme, industry roundtables that explore the potential for collaborative training opportunities with academia and industry innovators, and the creation of Informatics Skills Development Networks (ISDNs).

Figure D: Workforce development cycle



Further, the 'Data saves lives' strategy [11] outlines existing efforts to build analytical and data science capabilities, including building the profile of data and analysis as a profession through competency frameworks, networks, training, career opportunities and status, and the work of the Developing Data and Analysis as a Profession Board. Current initiatives include the NHSE Digital Workforce Programme within the System CIO/Director of Levelling-up Directorate, and the development and testing of a National Competency Framework for Data Professionals in Health and Care that will include a set of core competencies for health and care data professionals.[42]

A key part of this report's suggested educational approach involves continuation of the broader efforts to enable change and innovation in healthcare settings, as well as efforts to advance digital skills and capabilities within the workforce as important foundations for specific education and training in AI. When considering wider digital health and data-driven technology education, it may be appropriate to apply the approach this report has taken to structure the workforce into archetypes.

Digital infrastructure and organisational digital maturity are also key enablers of transformation through data-science and AI, without which large-scale adoption of AI technologies will not be possible.

These broader efforts should be considered a priority that will support educational and training offerings to develop healthcare workers' confidence in AI.

What happens next?

At a strategic level, this report can inform how HEE, educational and training providers and educators of healthcare workers can plan, resource, develop and deliver education to equip the workforce with the necessary AI knowledge, skills and capabilities.

Whilst the educational requirements in this report are not a detailed curriculum in themselves, they are intended to inform curriculum development for foundational AI education and advanced content for specific archetypes, and guide learning content for continuing education of qualified professionals.

Development of a foundational curriculum and the associated content will be an urgent priority.

The educational requirements will need to be adopted through change to educational curricula and the provision of AI-specific content, alongside concrete changes to roles and career paths for specialist AI healthcare workers. The next steps to achieve these can include:

Educational priorities

- **Produce foundational AI educational content.** Concerns about the lack of basic awareness and knowledge about AI amongst most healthcare workers highlight the urgent need for an accessible foundational AI education programme delivered in a scalable format.

- **Produce flexible post-qualification educational resources.** The diversity of skills, roles and educational needs in the existing workforce demands a flexible approach to delivering continuing professional development education. HEE, in collaboration with other partners in the public sector, academic and industry, can work towards producing and collating materials that can be accessed online and potentially personalised through self-assessment. These can be organised according to this report's archetypes, and the individual's experiences and interests, and could be available through a centralised online learning hub and/or other platforms like the NHS Digital Academy, the NHS Learning Hub, and AnalystX[43]. Curated education journeys will be required to guide learners to the appropriate information to meet their AI learning needs.
- **Develop product-specific training.** A collaborative effort between industry innovators and NHS staff in health settings will enable product-specific training to better reflect the local workflows and clinical settings and meet NHS user needs. The product specific training and a strategy for its use should be present from procurement through to workflow integration.

Next steps by workforce archetype

- **Shapers.** Shapers will largely work in national organisations that have traditionally been involved in regulation or guidance for healthcare, including within and beyond the remit of HEE and NHS. Both foundational education in AI technologies and more advanced training regarding the governance, validation and implementation of AI technologies would improve Shapers' abilities to translate their activities into the domain of data-driven algorithms and AI. This can include a healthcare-focussed educational offering for Shapers in national roles.
- **Drivers.** Interviewees for this research highlighted challenges relating to information technology, interoperability, and data governance as major barriers to deploying AI technologies in their settings. Prioritising education for the Driver archetype to support them in making the right strategic and governance decisions relating to AI may help to address these challenges. This can include development of specific educational resources or programmes for senior leaders to enable them to make informed decisions around specific technologies and prepare their organisations for deployment of AI technologies. It should also include engagement and support of ICS leaders to develop workforce plans that ensure appropriate digital, data and technology skills are being developed within the workforce.
- **Creators and Embedders.** Establishing and expanding training opportunities for Creators and Embedders should be considered a priority to fill the significant skill gaps highlighted by this research relating to

DDaT data and clinical informatics skills. These skills are vital not only to support creation and implementation of AI, but also for ongoing monitoring, assurance and audit of AI technologies. New opportunities should be established alongside efforts to upskill existing professionals with digital and data skills and establish flexible training opportunities for digital specialist clinicians. These efforts can be supported by the professionalisation and accreditation of these roles, the development of AI MDT teams, and the establishment of clear professional development and career pathways.

- **Users.** Development of user-related education and training will rely on engagement with undergraduate and postgraduate education providers. HEE does not directly provide education to healthcare professionals in training, but works with organisations like the Royal Colleges, national schools, and universities to advise on educational priorities. Further work is needed to work with these organisations and incorporate AI education into undergraduate and postgraduate curricula and to ensure these are aligned with other areas of education reform.

Many of these identified efforts are already underway, being led by Health Education England, the NHS Transformation Directorate, Integrated Care Systems and trusts, and industry innovators.

A forthcoming project, 'Establishing healthcare workers' confidence in AI', will involve engagement with these organisations and relevant groups and sharing of updates on progress being made on these efforts.

Chapter 1: Introduction

This research is a collaboration between the NHS AI Lab at the NHS Transformation Directorate and Health Education England. Its primary aim is to inform the development of education and training to develop healthcare workers' confidence in AI.

The **first report**[1] for this research, 'Understanding healthcare workers' confidence in AI', outlined a conceptual framework for understanding what factors influence confidence in AI among healthcare workers (see **section 1.2**). The main recommendation of that report was to **develop and deploy educational pathways and materials for healthcare professionals at all career points and in all roles, to equip the workforce to confidently evaluate, adopt and use AI.**

This second report aims to address that recommendation by identifying the key educational requirements to develop confidence in AI-driven technologies across the NHS workforce.

Audiences for this report

At a strategic level, the report can inform how Health Education England, educational and training providers and educators of healthcare workers plan, resource, develop and deliver educational offerings to equip the workforce with necessary knowledge, skills and capabilities.

Educational and training providers include (but are not limited to) the NHS Digital Academy, Medical schools and other healthcare undergraduate and postgraduate programmes, Council of Deans, National Association of Clinical Tutors, Royal Societies and colleges, and other private and voluntary sector providers.

More specifically, the report can assist these entities and individuals to develop specific curricula and content for their educational and training offerings through the areas of knowledge, skills and capabilities listed in **Chapter 3** and **Appendix A**.

The research involved a review of academic literature and semi-structured interviews exploring experiences of developing and using AI technologies in healthcare settings. Interviewees included healthcare workers in primary and hospital care settings; industry innovators; representatives of related regulatory and arm's length bodies; and academics who work at the intersection of AI, healthcare, education and clinical confidence.

The research did not include workers and carers in social and community care settings, although some of the findings may be relevant to aspects of their work.

Appendix B provides a list of the individuals and organisations interviewed for this research.

1.1 Background

This research – a collaboration between **Health Education England** and the **NHS AI Lab** at the NHS Transformation Directorate – has its origins in the Topol Review (2019),[3] which explored how to prepare the UK's healthcare workforce to master digital technologies for patient benefit. The Topol Review recommended the NHS should develop a workforce able and willing to transform it into a world leader in the effective use of healthcare Artificial Intelligence (AI) and robotics.

The Topol Review was followed by several initiatives in relation to supporting the development of digital, data, technology (DDaT) and clinical informatics skills in the NHS. It is important to note the nomenclature and responsibilities for roles involving these skills vary across these initiatives, and can include 'DDaT data specialists', 'data scientists', 'data analysts', 'data engineers', 'clinical scientists', 'clinical informaticians', 'clinical bioinformaticians', 'digital professionals', and 'AI professionals'. Further work is needed to reach consensus on the terminology and clarify links across these roles.

The initiatives include:

- The Health Education England (HEE) report 'Data driven healthcare in 2030: Transformation requirements of the NHS digital technology and health informatics workforce' published in March 2021.[7] The report was commissioned by HEE's Digital Readiness programme to identify the capacity and capability challenges facing the NHS digital technology and informatics workforce in the next 10 years. It projected the need for an additional 32,000 whole-time equivalents (WTEs) within the workforce to reach a forecasted size of 78,000 WTEs in 2030. The highest increase has been projected in clinical informatics professionals including data analysts, data scientists, clinical informaticians, statisticians and biostatisticians, health economists and clinical digital service owners.
- The HEE report 'The future of clinical bioinformaticians in the NHS' published in July 2021, which builds a comprehensive understanding of the factors related to the commissioning, training, and employment of clinical bioinformaticians in the NHS.[8]
- 'Putting data, digital and tech at the heart of transforming the NHS' published in November 2021, sets out recommendations for a shift in culture, operating model, skills, capabilities and processes to put data, digital and technology at the heart of how NHS transforms health services.[9]
- The NHS 'Year of the digital profession 2022' initiative, which involves a five-year strategy and roadmap to build a sustainable digital and data workforce.[10]
- The Goldacre Review ('Better, broader, safer: Using health data for research and analysis'), published in April 2022, exploring actions for better, broader, and safer use of NHS patient records to drive innovation and save lives. The review made several recommendations for the NHS workforce and needed education to support the efficient and safe use of health data, including a call to expand the workforce of data analysts and promote shared learning across sites.[4]
- The 'Data saves lives: reshaping health and social care with data' strategy published in June 2022, which sets out the strategy for using data to bring benefits to all parts of health and social care, including direct patient care, population health, improvement of care services and research and innovation.[11]
- The 'A plan for digital health and social care' report published in June 2022, which sets out a roadmap for the digital transformation of health and social care. It consolidates national digital goals and investments into one single action plan to equip the system digitally for better care, support

independent healthy lives, accelerate adoption of proven tech, and align oversight with accelerating digital transformation.[12]

Specific to AI technologies, HEE has established the Digital, AI and Robotics Technologies in Education (DART-Ed) programme to understand the impact of advances in AI on education and training needs. This research will build also on the AI Roadmap,[13] published by HEE and Unity Insights in January 2022. The Roadmap provides an understanding of the use of AI and data-driven technologies that currently exist in the healthcare system, the uptake of these new technologies, and their impact on the workforce. **Box 1** lists the Roadmap's main findings.

Supporting healthcare workers to feel confident in identifying when and how to use AI is a main objective of the NHS AI Lab, and a key component of its vision for the safe, effective, and ethical adoption of AI technologies across health and care. This research will support the Lab's commitment to empower healthcare workers to make the most of AI, including making the best of their expertise, informing their decisions, and saving them time to focus on patient care.

Box 1. AI Roadmap – Main findings

The Roadmap[13] involved an extensive horizon scanning exercise to capture information on 240 AI technologies at various stages of deployment in NHS sites.

Distribution of AI technologies: out of the 240 technologies, 'Diagnostic' was the most represented type with 34%, closely followed by 'Automation/Service efficiency' at 29%. 'P4 Medicine' and 'Remote monitoring' technologies accounted for 17% and 14% of technologies respectively. Within the 'Diagnostic' type, 'Imaging' solutions and 'Cardiorespiratory and neurology' solutions were at respectively 49% and 27%.

Key clinical areas using AI: the database included 67 clinical areas. After 'Multiple clinical areas' (selected for 23% of technologies), the most selected options were 'Clinical Radiology' (11%), 'Cardiology' (9%) and 'General Practice' (8%). The percentage of Automation/service efficiency technologies can explain why 'Multiple clinical areas' was so often selected, as they can be used in a multitude of settings.

Most affected workforce groups: 155 workforce groups (developed based on the occupational codes) were used to describe the NHS workforce. The top five workforce groups who have been identified as direct users of AI technologies are 'Medic, Clinical Radiology' (with 15% of technologies), 'Medic, General Practice' (13%), 'Non Clinical, Admin' (10%), 'Diagnostic Radiographer' (8%) and 'Medic, Cardiology' (8%).

1.2 A framework for understanding confidence in AI

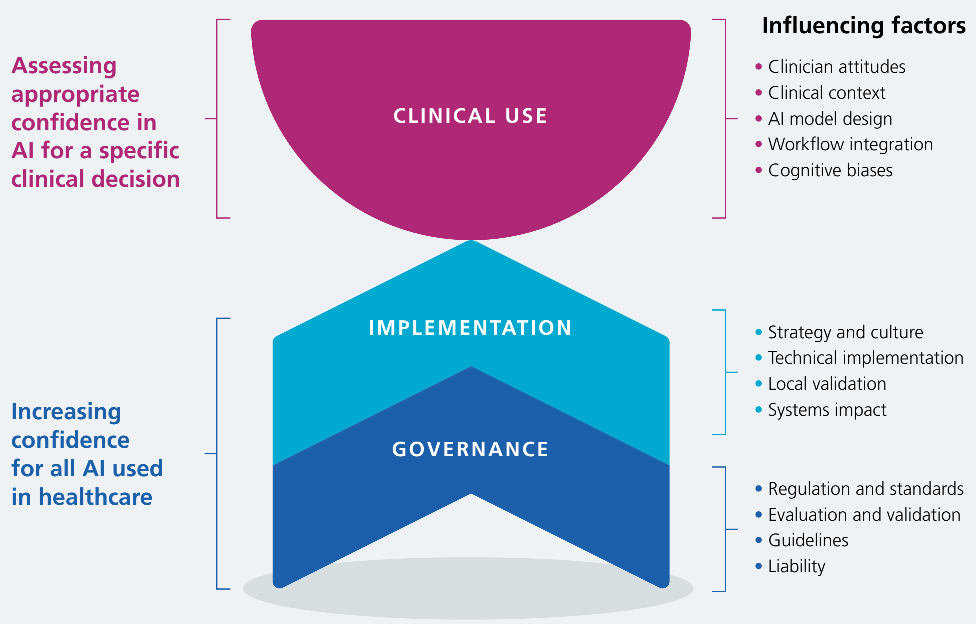
The **first report**[1] presented a framework for understanding what influences confidence in AI within health and care settings, which was developed following analysis of the academic literature and the interviews conducted for this research.

Establishing confidence in AI can be conceptualised as:

- **Increasing confidence in AI by establishing its trustworthiness (applies to all AI used in healthcare)**
  - Trustworthiness can be established through the **governance** of AI technologies, which conveys adherence to standards and best practice, and suggests readiness for implementation.
  - Trustworthiness can also be established through the robust evaluation and **implementation** of AI technologies in health and care settings.
  - Increasing confidence is desirable in this context.
- **Assessing appropriate confidence in AI at the point of use (applies only to AI used for clinical decision making)**
  - During clinical decision making, clinicians should determine appropriate confidence in AI-derived information and balance this with other sources of clinical information.
  - Appropriate confidence in AI-derived information will vary depending on the technology and the clinical context.
  - High confidence is not always desirable in this context. For example, it may be entirely reasonable to consider a specific AI technology as trustworthy, but for the appropriate confidence in a particular prediction from that technology to be low because it contradicts strong clinical evidence or because the AI is being used in an unusual clinical situation. The challenge is to enable users to make context-dependent value judgements and continuously ascertain the appropriate level of confidence in AI-derived information.

Figure 1 illustrates the conceptual framework and lists corresponding factors that influence confidence in AI. These comprise factors that relate to governance and implementation, which can establish a system's trustworthiness and increase confidence. Clinical use factors affect the assessment of confidence during clinical decision making on a case-by-case basis (see **first report**[1] for detailed analysis of these factors).

Figure 1: Framework for understanding confidence in AI among the healthcare workforce



1.3 Terminology

This report uses the terms '**AI**' and '**AI technologies**' to describe the use of digital technologies to create systems capable of performing tasks commonly thought to require intelligence. These can include algorithms using statistical techniques that find patterns in large amounts of data, or to perform repetitive cognitive tasks with data, without the need for constant human oversight.

AI technologies have the potential to support existing clinical capabilities in diagnosis and screening, drug discovery, digital epidemiology, and personalised medicine,14 as well as optimising organisational resources, system efficiencies and clinical workflows.

Clinicians, as referred to in this report, include healthcare workers making a patient-specific decision that affects patient care, and may include nurses, paramedics, allied health professionals, doctors, and other specialist healthcare staff groups.

Industry innovators refer to private sector developers and providers of AI technologies.

Chapter 2: Workforce Archetypes

This chapter provides an analysis of various workforce roles and responsibilities, grouped into five archetypes that relate to how AI technologies are developed, deployed, and used in health settings.

The archetypes provide the foundation of **Chapter 3**'s suggested educational pathways.

Defining the archetypes

Interviewees for this research described various roles and responsibilities that relate to how AI technologies are developed, implemented and used in health settings. Following an analysis of these descriptions, this report presents five groupings, referred to as **archetypes**, as detailed in **Figure 2**.

The five archetypes include Shapers, Drivers, Creators, Embedders and Users. Individuals acting as each archetype will have different knowledge and skills requirements to confidently develop, implement or use AI technologies, and hence specific educational needs as detailed in **Chapter 3**.

The archetypes do not necessarily align with traditional professional groups (for example, doctors, nurses, allied health professionals), specialisms or levels of seniority, but depend solely on an individual's role in the development, implementation and use of AI technologies. A specific archetype may include individuals from various professional and managerial backgrounds.

Figure 2 provides examples of individuals who may take on each archetype role, including references to existing professional roles at the NHS. There is no implied hierarchy of responsibilities or strict mapping between existing roles and the archetypes. The examples provided for individuals who may take on an archetype role are not exclusive and will depend on the individuals' skills, local team structure and project scope.

Although most healthcare workers will have responsibilities associated with one archetype, the archetypes are not mutually exclusive. For example, a clinician could be involved in co-creating AI technologies (as a Creator), validating AI technologies procured for use within their setting (as an Embedder) and undertaking clinical work using AI technologies (as a User). These responsibilities may involve single or multiple projects.

Roles and responsibilities will also vary according to the specific requirements of AI technologies, including the level of clinical risk, the intended use of the product and the impact on clinical workflows.

The table also includes roles that are not widely seen in healthcare settings – particularly in relation to the Creator and Embedder archetypes. These new specialist roles will need to be established through job creation, recruitment, and data-science specific training programmes, as discussed in **section 4.2**.

The five archetypes relate to a person's role, however it is common for people in similar roles to respond quite differently to new ways of working; some are enthusiastic early adopters, others much later adaptors, and most will fall somewhere in between. There are numerous motivational and practical issues that explain this, and NHS England is conducting research in 2022 to better understand these motivational factors and how they might inform new ways to support, educate and train the workforce.

Figure 2: AI workforce archetypes

Shaper

Set the direction for AI policy and governance at a national level

Example responsibilities

- Decide on AI policies within healthcare at a national level
- Author and enforce regulation for AI technologies, for professionals creating and using AI and for healthcare settings implementing AI
- Create guidelines for the creation, procurement, deployment and use of AI
- Produce national procurement frameworks for AI technologies
- Guide training of healthcare professionals

Examples of individuals who may take on this archetype role

- NHS leadership and policymaking teams
- Executives at arm's length bodies (ALBs)
- Product regulators
- Regulators of healthcare workers
- Regulators of healthcare settings
- Developers of healthcare technology standards
- Developers of procurement guidelines
- Developers of product development and implementation guidelines
- Developers of clinical guidelines
- Professional educators

Driver

Champion and lead AI development and deployment at a regional/local level

Example responsibilities

- Set the vision for digital and AI transformation at a regional/local level
- Champion AI technologies, by communicating the value and benefits, as a recognised and trusted leader
- Lead the systems change required to deploy AI technologies effectively
- Lead strategic decision-making related to AI procurement and deployment at a regional/local level

- Implement local AI governance infrastructure to ensure that AI is being deployed safely
- Promote funding and resource allocation for AI at a regional/local level
- Recruit and lead NHS AI multi-disciplinary teams (MDT)

Examples of individuals who may take on this archetype role

- NHS regional leaders
- ICS boards
- Chief Information Officers (CIO)
- Chief Clinical Information Officers (CCIO)
- Project Management Office (PMO) leads
- Digital transformation leads
- Service leads
- Clinical commissioners

Creator

Create AI technologies for use in healthcare settings

Example responsibilities

- Create AI algorithms independently or through collaboration with industry innovators and/or academia
- Align AI algorithm development with appropriate regulation, evidence standards and technical guidelines
- Conduct user research with healthcare professionals
- Test and validate AI algorithms during product development and subsequent releases
- Iterate and improve AI algorithms
- Evaluate AI in terms of performance and clinical impact
- Set up systems for the ongoing monitoring of AI algorithms to assess for any model drift
- Conduct clinical trials of AI algorithms

Examples of individuals who may take on this archetype role

- Specialist digital clinicians
- DDaT data professionals (data analysts, data engineers, data scientists)
- Clinical informatics professionals, including clinical scientists (such as clinical bioinformaticians)
- Software engineers
- NHS AI researchers

Embedder

Implement, evaluate and monitor AI technologies deployed within healthcare settings

Example responsibilities

- Implement and integrate AI systems in healthcare settings
- Conduct technical implementation and systems integration
- Ensure that healthcare data used by AI technologies is managed safely and securely
- Establish and manage safety processes for reporting AI technology issues and back-up pathways for when products fail
- Conduct local validation of AI technologies if required
- Evaluate AI in terms of performance and clinical impact
- Participate in ongoing monitoring of AI technologies assessing for any model drift, including designing and performing algorithmic audits
- Design, deliver and continuously update product-specific user education, guiding users about how to use AI technologies safely and effectively

Examples of individuals who may take on this archetype role

- Specialist digital clinicians
- DDaT data professionals (data analysts, data engineers, data scientists)
- Clinical informatics professionals, including clinical scientists (such as clinical bioinformaticians)
- Statisticians
- Information technology (IT) teams
- Information governance (IG) teams
- Clinical Safety Officer (CSO) and clinical safety teams
- Knowledge Managers

User

Use AI technologies within healthcare settings

Example responsibilities

- Use AI within healthcare settings in accordance with guidelines
- Employ appropriate safety measures related to the use of AI

- Communicate with patients and the public about AI

Examples of individuals who may take on this archetype role

- Clinicians using AI
- Non-clinical staff using AI
- Clinical researchers using AI

Box 2 provides a fictional case study that demonstrates example roles and responsibilities for each archetype for a fictional AI technology.

Box 2. AI workforce archetypes - Fictional case study

This fictional case study involves the creation and deployment of an imaging-based AI technology within a healthcare setting. The aim of this case study is to outline examples of the possible roles and responsibilities for different archetypes during the development and deployment of an AI technology. Only some of the responsibilities listed below will be applicable to other products and implementations.

All product and organisation names used in this case study are fictional.

Summary: A chest X-ray triaging AI product (tri-X) is co-designed between Linchester ICS and an industry innovator, Triadix. The technology is designed to help manage the radiology workflow by prioritising chest X-rays for review by radiologists. Following related regulatory approvals and evidence of robust performance, the technology is later procured and deployed by Nymouth ICS.

Shaper

Example responsibilities

- Create the AI development standards including AI product development, data security and information governance that are followed by the tri-X developers at Triadix and Linchester ICS
- Create the regulatory framework used to classify and appraise tri-X
- Produce evidence and validation standards used to evaluate tri-X
- Develop guidelines for conducting clinical trials of AI products

- Develop clinical guidelines for the use of tri-X
- Determine the NHS deployment strategy used in the national roll out of tri-X
- Develop national procurement guidelines and frameworks used to purchase tri-X
- Professionally regulate clinicians involved in developing, validating and using tri-X
- Regulate healthcare settings using AI products used to assess the settings deploying tri-X
- Produce guidance on liability to educate those deploying and using tri-X

Driver

Linchester ICS

Example responsibilities

- Advocate for budget for digital health/AI development at Linchester ICS
- Decide on the ICS strategy for co-creation projects including commissioning arrangements for commercial partners, financial agreements, data sharing arrangements
- Ensure the ICS workforce plan addresses data and technical skills and roles
- Establish an ICS AI multi-disciplinary team (MDT) consisting of clinical specialists, data scientists, clinical scientists, regulatory and safety teams to work on AI co-creation projects
- Create a process for the selection and prioritisation of AI projects within the ICS
- Establish pathways and infrastructure for piloting and clinically evaluating AI products within the ICS
- Commission Triadix as a commercial partner to co-create tri-X
- Formulate an intellectual property agreement with Triadix
- Formulate a commercial commissioning agreement for the wider roll out of tri-X
- Ensure that appropriate regulatory standards are being adhered to when creating tri-X and the product development aligns with appropriate guidelines

Nymouth ICS

Example responsibilities

- Decide on an ICS procurement strategy used to guide the purchase of tri-X
- Establish an ICS AI MDT consisting of clinical product specialists, data scientists, regulatory and safety teams to work on AI co-creation projects
- Conduct horizon scanning to assess possible digital solutions to clinical problems
- Evaluate tri-X alongside other AI and non-AI products to determine the best solution to clinical problems with advice and guidance from the AI MDT
- Verify that tri-X has met appropriate regulatory and safety standards and aligns with technical and clinical guidelines for the proposed use case
- Agree on contracts to procure tri-X including financial agreements and data sharing arrangements
- Ensure that the ICS AI MDT have the resources to monitor tri-X over time and to analyse the impact of the product on system efficiency and clinical outcomes
- Lead and manage the systems changes required to implement tri-X within clinical pathways including the workforce impact, technological infrastructure and user training

Creator

Linchester ICS and Triadix

Example responsibilities

- Undertake problem discovery sessions with numerous stakeholders, map out workflows and explore the clinical issue to be solved by tri-X
- Ensure that there is an appropriate data set available to address the problem, evaluating the data for potential bias and generalisability
- Work within an AI MDT alongside Triadix to create the tri-X AI model
- Co-create tri-X with users. Conduct regular user research sessions to get feedback on how to improve the product and add value to users
- Ensure tri-X aligns with safety and regulatory standards working closely with Linchester ICS safety and regulatory team from the outset

- Test the algorithm using internal and external validation methods, iterating and improving the model until accepted accuracy and safety levels are reached (alongside Embedders)
- Conduct prospective clinical studies of tri-X in line with Linchester ICS requirements and national evidence standards to demonstrate efficacy (alongside Embedders)
- Conduct post market follow up to assess and monitor performance, and act upon any model drift (alongside Embedders)

Embedder

Nymouth ICS

Example responsibilities

- Lead the technical implementation of tri-X including systems integration and information governance
- Conduct a clinical safety review of tri-X and ensures there are appropriate protocols in place for systems failure and for reporting errors
- Review and critically appraise the internal and external validation results for tri-X
- Review and critically appraise prospective clinical studies of tri-X
- Evaluate the need for local product validation, and conduct this analysis if required
- Assess the regulatory compliance of tri-X
- Advise ICS Drivers regarding AI product procurement decisions
- Advise on, and assist with, the systems change processes involved in the introduction of tri-X
- Create and deliver product-specific user education for tri-X both independently and through collaboration with Triadix. Continue to deliver education and training updates to address product iterations
- Provide advice and support for users of tri-X

User

Example responsibilities

- Use tri-X (as a radiographer or radiologist within Linchester ICS and Nymouth ICS) to prioritise X-rays for review
- Undertake appropriate product-specific user training for tri-X and keeps this up to date
- Use tri-X in accordance with clinical guidelines and guidance from professional regulators
- Identify and act upon situations in which tri-X may be prone to error, overriding tri-X decisions where appropriate.
- Use tri-X to prioritise cases appropriately, with awareness of the potential for bias in the human-AI interaction for clinical decision making
- Action fall-back clinical pathways if the tri-X product fails
- Report suspected errors and any safety concerns identified when using tri-X

Chapter 3: Suggested Educational Approach

This chapter provides a suggested approach to educating and training the existing and future healthcare workforce to develop confidence in AI technologies. The suggested approach is informed by the insights and findings presented in the **first report**[1] and the resulting framework for understanding factors influencing confidence in AI within health settings (see **section 1.2**).

At a strategic level, this suggested approach can inform how Health Education England, education and training providers for healthcare workers, managers at health and care settings, and industry innovators plan, resource, design and deliver educational offerings for AI in health settings.

The areas of knowledge, skills and capabilities listed in this chapter and **Appendix A** can also assist these education providers to develop curricula and content for training programmes and educational materials.

The chapter ends with a presentation of several personas that highlight potential educational journeys for healthcare workers in developing, implementing and using AI technologies in the future.

3.1 Overview of suggested approach

The insights provided in the **first report**[1] show the importance of broad educational efforts across the NHS workforce. Interviewees for this research observed that in many health settings, industry innovators are currently shaping the workforce's knowledge of AI, which highlights the importance of vendor-neutral educational materials, and sources that highlight the potential value, limitations and risks of AI for healthcare. Ultimately, healthcare workers should be supported to critically appraise the technologies, evidence and information provided by private sector providers.

As noted by interviewees, the broad educational challenge is to provide the right resources to the right people, and to build skills and capabilities across the workforce in the most efficient and effective way possible.

This approach to educating the healthcare workforce can be informed by previous experiences within the NHS learning, both in terms of what has worked well and what hasn't. Examples include the introduction of computers, the introduction of imaging management software in radiology and the transition to electronic health records (EHRs). These transitions required a mixture of widespread training and skills acquisition, whilst also establishing specialist technical teams with the expertise to deploy and support these technologies.

Similarly, basic understanding of AI will be required for all healthcare workers who might use such technologies, while further knowledge and skills requirements will depend on profession, roles and responsibilities related to AI, the technologies being used, and the settings where they are deployed.

Based on these observations, **Figure 3** illustrates the suggested approach to education and training for AI in healthcare.

Figure 3: Suggested education and training approach

1) As essential groundwork to AI education and training, continuation of the broader efforts to enable the adoption of change and innovation in healthcare settings, as well as efforts to advance **digital literacy, skills, and capabilities** within the workforce (such as the digital transformation pathways outlined in the NHS Long Term Plan[2], the Topol[3] and Goldacre[4] reviews, the plan for digital health and social care[5], and 'Data saves lives' strategy[11])

2) Development and provision of **general education and training for AI** through:

- **a) foundational** AI education across the whole healthcare workforce, including basic AI literacy and awareness of the limitations and risks of using AI technologies
- **b) advanced** AI education that is specific to the workforce archetypes, including development of skills and capabilities

3) Provision of **product-specific** training for users of **each AI technology** during its deployment

Knowledge, skills and capabilities taxonomies

The requirements for knowledge, skills and capabilities in this chapter and **Appendix A** are organised according to progressive taxonomies. The taxonomies, illustrated in **Figure 4**, have been developed as a pragmatic approach to define levels of required knowledge and skills, with implications for the nature and degree of related education and training efforts.

The taxonomies have been informed by other existing approaches to education and training, including Bloom's taxonomy[19] and competence-based approaches to skills hierarchies.[20]

The taxonomies are based on the principle that knowledge underpins skills, which requires theoretical understanding to underpin practical application. Skills and capabilities enable people to perform a task, contribute to, or lead an aspect of a project.

Figure 4: Taxonomies

Knowledge taxonomy

The following statements summarise the progressive outcome of knowledge-based education and training efforts from a learner's perspective:

1. **Awareness**: 'I am aware of this concept and its relevance to my healthcare practice'
2. **Familiarity**: 'I know more detail about this topic and can use this knowledge to guide my practice and make decisions'
3. **Understanding**: 'I understand this subject in depth and can synthesise my knowledge to apply it to new and challenging situations. I can teach and support others within my area of practice'

Skills and capabilities taxonomy

The following statements summarise the progressive outcome of skills-based education and training efforts from a learner's perspective:

1. **Capability**: 'I am able to perform this task either independently or as part of a team'
2. **Proficiency**: 'I am experienced in this area and can lead on this aspect of a project, guiding and educating others to drive success'

Progression from awareness to understanding suggests increasing exposure to educational materials that can enable learners to synthesise and critique information, in the spirit of Bloom's educational taxonomy. If an individual 'understands' a given topic they can be assumed to also have awareness and familiarity with that topic.

Capability implies a level of experience appropriate for contributing to a project as part of a wider team. Proficiency is associated with greater experience and expertise and implies the ability to lead an aspect of the project. If an individual is 'proficient' in a skill, they can be assumed to be capable and to have appropriate understanding of the subject.

For both knowledge and skills, the educational content required will vary with each taxonomy level. The details of the provided education, and how it is assessed, will depend on the professional group, career level and role of the individual. These factors need to be considered when developing curricula informed by this approach.

3.2 Foundational AI education for all healthcare workers

This section outlines key educational and training requirements to develop AI-related knowledge across the whole healthcare workforce.

This foundational AI education will aim to develop **awareness and familiarity**, as opposed to understanding, skills and capabilities in healthcare workers. Education and training at this foundational level will need to be delivered to large numbers of existing staff and incorporated into educational programmes for future professionals.

Workers who may take up any of the archetype roles will require this foundational education prior to any advanced educational offerings.

Table 1 lists the educational requirements for foundational AI education, organised according to the factors that influence confidence in AI (see **section 1.2** and the **first report**[1]).

It includes requirements for AI-specific literacy as an initial area of focus. As noted in the suggested pathways outlined in **section 3.1**, broader efforts to advance digital literacy amongst healthcare workers will be essential groundwork to AI education and training. AI-specific literacy can be supported by these broader efforts, including data literacy initiatives in development like 'Dataversity' within the AnalystX platform.[43]

The requirements in **Table 1** can support the design of education and training programmes for various settings. These approaches could include incorporating the suggested requirements into undergraduate and postgraduate curricula, providing educational offerings tailored to specific roles and specialities, and offering online open access courses for continuing professional development, that can be tailored to individual need. The requirements can also inform considerations for specialist sections in existing provision, like the NHS Digital Academy offering, and related content in the NHS Learning Hub.

These educational efforts will need to extend beyond simply providing access to existing external education resources. In the context of educational material for data analysts, the Goldacre Review[4] highlighted the current availability of 'an almost limitless array of self-directed online teaching through services such as Coursera, or some MOOCs (Massive Open Online Courses), but no clear signposting or curation of "journeys" through these courses, or guidance on which to choose.' This is equally applicable to AI technologies, where a plethora of technical educational material is available. However, there is a dearth of material tackling some important healthcare-specific challenges like good practice in AI-assisted clinical decision making. A clear, structured educational strategy will be required to guide learners to the appropriate information to meet their AI learning needs.

Table 1: Requirements for foundational AI education

Taxonomy: • **Knowledge** + **Skill**

AI literacy

- Awareness of examples of AI applications and algorithms used in health and care
- Awareness of types of healthcare problems best suited to AI
- Awareness of how data-driven algorithms learn
- Familiarity with the definitions of algorithms, AI, machine learning and deep learning and how they relate to each other

Governance

Regulation and standards

- Awareness of the importance of compliance with medical product regulation for AI (including UKCA/CE marking by MHRA, and GDPR), including applicable standards (for example, NHS Digital and ISO standards) for product development and risk management.
- Familiarity with any developed guidance from regulators of healthcare workers on the development and use of technology including AI (including GMC, NMC, HCPC)
- Familiarity with the regulation of healthcare settings and how this applies to the use of technology (including relevant guidance from care inspectorates like the CQC)

Evaluation and validation

- Awareness of how AI algorithms are tested and validated

- Awareness of the difference between internal validation, external validation, and prospective clinical studies
- Awareness of the importance of reproducibility and generalisability of AI models, and the risk of data and model bias in AI, which may disadvantage specific groups or reinforce existing health inequalities

Guidelines

- Familiarity with where to find clinical guidelines that apply to using AI technologies
- Familiarity with good practice for use of AI when no product-specific clinical guidelines exist (for example, applying the principles of Good Medical Practice15 or Good Scientific Practice16)

Liability

- Awareness of issues relating to personal and organisational liability for AI technologies

Implementation

Strategy and culture

- Awareness of the potential value of AI technologies for healthcare systems and for patients
- Awareness of the main risks of deploying AI technologies into clinical settings
- Awareness of examples of successful implementation of AI technologies in healthcare settings
- Awareness of the importance of a multi-disciplinary approach to AI implementation that involves clinical, technical and managerial roles
- Awareness that AI technologies may lead to inequitable distributions of patient outcomes or disadvantage certain patients

Technical implementation

- Awareness of the need for interoperability and seamless integration of AI systems

- Awareness of the importance of ongoing monitoring to ensure continued safe, ethical and effective use
- Familiarity with information governance principles and how these apply to patient data

Clinical use

AI model and product design

- Awareness of the limitation of ‘black-box’ AI, and attempts to address it including transparency initiatives and/or explainable AI
- Awareness of the potential risk of deskilling of the clinical workforce as a result of deploying AI technologies, and the importance of considering ways of mitigating this during product implementation
- Awareness of the potential risk of deskilling of the clinical workforce when using AI technologies, and the importance of considering ways of mitigating this during product implementation
- Familiarity with the difference between autonomous AI and human-in-the-loop systems
- Familiarly with the role and responsibilities of clinicians when using AI for CRDM

Cognitive biases

- Awareness of the risk of users being under- or over-confident in information derived from AI
- Awareness that cognitive biases (including automation bias and rejection bias) can affect decision making with AI

Interface with patients

- Awareness of the importance of fairness, transparency, and accountability when deploying AI technologies
- Awareness of the challenges of empowering patient choice when involving AI in CRDM and care pathways

3.3 Advanced AI education for specific workforce archetypes

The broad aim of the advanced AI education will be to develop in-depth understanding of, and skills related to, various subject areas. This will enable healthcare workers to lead different aspects of the deployment of AI technologies in health settings and advise others.

Interviewees for this research identified several key principles that can guide the education and training for each archetype, as well as non-educational factors that can enable such education and training. These are listed in **Box 3**.

Appendix A provides further related analysis and lists the advanced educational requirements across the workforce archetypes and the factors that influence confidence in AI.

These advanced requirements will be additional to the foundational requirements (outlined in **section 3.2**) and the requirements for product-specific education (**section 3.4**).

Box 3: Guiding principles and enabling factors for advanced AI education

Shaper

- Educating Shapers is a priority, as their decisions will have downstream effects on all other archetypes through governance, guidance, and system transformation.
- The safe, effective and ethical use of AI in healthcare should be at the heart of Shaper education.
- Shapers across different organisations should be encouraged to work collaboratively to share knowledge, align messaging and create complimentary frameworks in relation to AI technologies.
- Awareness and appreciation of developments outside the expertise of the Shaper and their organisation is key to joined-up governance and regulation.
- Engagement of Shapers with the Creator and Embedder archetypes is vital to ensure practical frameworks that enable rather than constrain digital transformation with AI.

Driver

- Drivers need to be equipped to ask the relevant questions of an AI technology prior to procurement or commissioning (see Table A3). They should be able to critically appraise AI to make evidenced strategic commissioning decisions.

- Drivers should promote a workplace culture that embraces innovation, entrepreneurship, continuous learning and multidisciplinary working.
- Drivers should champion a culture of transparency and diversity to promote fairness and inclusivity in the development and use of AI.
- Drivers should understand the value of AI specialists and champion AI multi-disciplinary teams (MDTs).
- Educational resources for Drivers should be flexible, efficient, and accessible.

Creator

- Creators should understand both the technical and clinical aspects of the problem addressed, and the AI approach employed.
- Creators should understand and appreciate user design and workflow integration.
- Knowledge of the potential clinical consequences of using AI and the legal positions of creators, providers and users of AI technologies are essential for Creators.
- Fundamental statistical and data science literacy are crucial for Creators, enabling them to detect and mitigate risks from bias in algorithms.
- The development of diverse and inclusive AI multi-disciplinary teams (MDTs) can encourage co-creation of AI technologies and enable Creators to share their knowledge and expertise with others.
- Expansion of training for specialist data scientists and informaticians could equip more NHS professionals for Creator roles.
- Accreditation and recognition for AI co-creators and informatics specialists can professionalise this archetype and enable up-skilling.

Embedder

- Embedders can have different specialised skill sets including IT and IG specialists, data-scientists, software engineers, safety teams and specialist clinicians.

- Embedders should understand a broad range of topics at a detailed level, ranging from governance requirements and evidence evaluation to technical knowledge about AI algorithms, algorithmic biases and the importance of AI workflow integration for clinical confidence.
- Workforce transformation will be needed to equip the healthcare system with sufficient Embedders of AI technology. This will require:
  - Professionalisation of specialist embedder roles.
  - Expansion of training for DDaT data professionals and clinical informaticians
  - Upskilling of existing clinical and scientific trainees in education related to AI, with flexible training schemes and career opportunities, funded time and incentives for digital health training.

User

- Advanced education for Users should focus on the human-AI interaction and the impact of AI technologies on clinical reasoning and decision making (CRDM).
- Users should learn how to communicate with patients about AI technologies, acting as ‘AI counsellors’ to help guide patients in interpreting the results of AI and guiding them about issues like data security.
- Education for Users should be tailored by a professional group, guided by the clinical scenarios for AI in that area and the setting for their use (for example, emergency versus planned care).
- User education should reach clinicians in training as well as those who are fully qualified.
- AI foundational and advanced User education should be incorporated within existing undergraduate and post graduate curricula.
- Equitable access to training and support for existing clinicians will be required, at both foundational and advanced levels, including special efforts to engage and support the digitally unengaged or unconvinced.
- Support for existing trainees’ education will be needed, including study leave, funding and protected time for digital and AI skills training.

3.4 Product-specific user training

The diversity of applications for AI technologies in healthcare, and the way these technologies are designed and deployed in different health settings suggest that healthcare workers will require training that is specific to each technology that is introduced and used in their setting.

Factors like the technology's intended use, technical basis, user interface and workflow integration will inform specific educational requirements and training.

Interviewees for this research noted that, at present, most users of AI technologies rely on product providers (industry innovators) for training on their AI technologies. Currently, there are no standards or regulations governing the requirements for such training. Further, the burden of delivering such training may fall on small to medium-sized enterprises who may not have resources to educate large cohorts of NHS staff, across multiple settings.

Given these limitations, future training for specific AI technologies is likely to require a collaborative effort between industry innovators and internal teams in health settings. This will enable product-specific training that reflects the local workflows and clinical setting, enabling a more bespoke approach that will better equip users of that technology.

The HEE report 'Data driven healthcare in 2030' recommended developing a '*programme to develop professionals and managers in the field of IT education and training*.'[7] This is supported by the Goldacre Review, which recommends creating '*a technical team to house and develop continuing professional development resources.*' The review states that '*providing a team of technical specialists with adequate funding to develop, deliver, share, and curate training … will be essential if training is to be high-quality and up to date*'.[4]

As noted in **Box 3**, creating, delivering and continually updating product-specific user training as products iterate and change can be a key responsibility of AI-specific multi-disciplinary teams (MDTs). Specialist technical educator roles within these teams would likely be required to support such training.

Table 2 lists areas of knowledge and skills required concerning a specific AI technology to be deployed at a healthcare setting. These are intended to guide the information made available to users during AI product-specific training.

Table 2: Requirements for product-specific training

Taxonomy: • **Knowledge**
+ **Skill**

Governance

- Familiarity with the clinical guidelines that apply to the use of the AI technology
- Familiarity with the implications of using the technology outside of the guidelines
- Understanding of clinician liability for the product, including in the scenario when the output is incorrect and leads to patient harm
- Understanding of the legal implications of either using or ignoring an AI-derived information in CRDM, including current uncertainty relating to liability for AI in CRDM

Implementation

- Familiarity with the technology's intended use, and inclusion and exclusion criteria for that use
- Familiarity with reporting requirements for potential errors or safety concerns with the technology
- Familiarity with product specific factors which may affect fairness, transparency and equitable outcomes in the use of the technology

Clinical use

- Familiarity with who to contact with questions about the use, performance or monitoring of the AI technology
- Familiarity with the potential clinical consequences of false-positive and false-negative errors, and how these should be managed
- Familiarity with model limitations and situations where the AI technology is more likely to make an error or be unreliable, including the identification of potential 'outlier' cases

- Familiarity with how assisted decision making should be recorded in this scenario
- Familiarity with the pathway for patients to query decisions made with AI
- Understanding of factors that may influence how clinicians weigh the AI derived information in this specific scenario, including their level of clinical experience at the task
- Understanding of how any explanation or probability provided with a prediction from the AI should be interpreted in assisted clinical decision making
- Understanding of how the workflow integration might affect the interpretation of AI derived information, including the timing of AI information relative to clinician assessment.
- Understanding of how to respond to situations when the AI contradicts clinical intuition, and any processes in place in terms of referral, arbitration and documentation

+ Capable of weighing a prediction from the AI against other forms of clinical and demographic information during clinical decision making
+ Capable of counselling patients about the use of their data by the AI technology, and how this data is accessed, processed and stored
+ Capable of explaining this tool and its impact on CRDM to the patient, including access to patient communication materials
+ Capable of communicating the risks and limitations of the AI technology to guide the patient through decisions about their health

3.5 Educational routes and personas

The following personas represent examples of prospective roles and responsibilities in the healthcare workforce that relate to how AI technologies may potentially be adopted in health settings. The personas specify potential education and learning routes for these roles.

The personas are illustrative and speculative and are not intended to dictate rigid structures and systems, job roles, education routes or capability requirements. **The personas are provided to initiate discussions and further exploration of how education and training could be developed and delivered for the workforce.**

Shaper *Persona 1*

Role

Digital Health Technologies Director - Arm's Length Body

AI responsibilities

Manages an assessment pathway for digital health technologies (including AI) and the creation of clinical guidelines for these technologies.

Education journey

- Undergraduate biomedical sciences degree, followed by a Masters in Digital Health Technology Assessment.
- Started in entry role at arm's length body and completed an online foundational AI-education course.
- During first year at arm's length body, completed additional certified educational courses relating to healthcare product regulation and validation, which included developments in relation to AI technologies. Continually updates knowledge through online AI-related educational courses and educational events involving other Shaper organisations.

Shaper *Persona 2*

Role

Head of Data and Transformation - NHS England

AI responsibilities

Oversees development of policies and implementation of interventions that aim to create safe and efficient environments to collect, store, and share data for research, planning and improvement, including in relation to AI technologies.

Education journey

- Undergraduate degree in data science.

- Held data consulting roles initially in private sector and then NHS trusts, while completing a Diploma and Masters in digital health.
- Completed a foundational AI-education course as part of a broader educational programme on digital leadership, and self-directed advanced modules relating to the regulation and evaluation of AI technologies.

Driver *Persona 1*

Role

Chief Nursing Information Officer (CNIO) - Linchester IC

AI responsibilities

Sits on the Linchester ICS board. Key decision maker in procurement of AI technologies for the ICS with a particular focus on technologies to be used by nursing staff and healthcare assistants. Collaborates with, and oversees, Embedders within the trust to evaluate deployed technologies, conduct ongoing monitoring, optimise workflows, lead clinical product safety, and deliver education to staff about using AI technologies. Line manages a team of specialist digital health nurses within the trust.

Education journey

- Nursing undergraduate degree that included a foundational AI education programme as part of curricula.
- After becoming a Band 6 nurse, completed a PG diploma in clinical informatics through a self-directed online learning platform.
- Accepted onto digital health specialist nurse training programme and worked within a trust AI MDT.
- Completed a PG certificate in education to guide the delivery of product-specific AI education.
- Over several years, built up competencies required for a CNIO role application. Continually updates knowledge through open access digital training courses that include data science, digital health and AI-related content.

Driver *Persona 2*

Role

Chief Data officer (CDO) - Linchester IC

AI responsibilities

Sits on the Linchester ICS board. Leads the data strategy within the ICS, including the storage and management of patient data, data security and privacy, data interoperability and the management of the ICS Trusted Research Environment (TRE) that is accessed by academics and innovators to conduct research and product development. Has a key role in the procurement of AI technologies for the ICS with a particular focus on requirements for data and interoperability. Collaborates with, and oversees, Creators and Embedders within the trust to evaluate potential technologies, implement AI and undertake ongoing monitoring and research. Represents all ICS data scientists and NHS analysts at ICS board level and ensures they have appropriate resources and training opportunities.

Education journey

- Undergraduate degree in computer and data science.
- Worked for five years in data science roles in the advertising industry.
- Applied to NHS data science role. Obtained a professional health data-science qualification in post, using their existing data science skills, combined with undertaking additional healthcare and clinical informatics training, to meet the requirements for registration.
- Completed further self-directed modules on AI-related content.
- Progressed to senior CDO (Chief Data Officer) role after working for several years within the trust. Continually updates knowledge through open access digital training courses.

Creator *Persona 1*

Role

Clinical scientist: Data scientist and AI - Linchester IC

AI responsibilities

Co-creates AI algorithms with Embedders, Users and industry partners at Nymouth ICS. Takes an active role in the design and validation of AI algorithms during product development and subsequent releases. Evaluates AI in terms of performance and clinical impact. Sets up and maintains pathways for the ongoing monitoring of technologies within the trust.

Education journey

- Undergraduate degree in physiology followed by a Masters in data science.
- Completed clinical scientist training in clinical informatics that incorporated a foundational AI education programme and specialised modules for Creators.
- Undertook additional courses at the National School for Healthcare Science in AI design and development within healthcare. Continually updates knowledge through open access digital training courses.

Creator *Persona 2*

Role

Consultant dermatologist with digital health specialist interest - Nymouth ICS

AI responsibilities

Co-creates dermatology AI algorithms with the Embedders, and industry partners at Nymouth ICS. Takes an active role in the clinical UX design of AI products ensuring they are user friendly and add value for clinicians and patients. Assesses and guides how best to integrate AI technology into clinical workflows. Conducts prospective clinical evaluation of AI products comparing them to existing best practice. Analyses the impact of AI outputs on clinician decision making to guide product development. Undertakes clinical validation of AI algorithms alongside Embedders. Evaluates AI in terms of performance and clinical impact.

Education journey

- Completed medical training through undergraduate degree, foundation programme, core medical training and specialist training.
- Worked as senior dermatology registrar in Nymouth ICS.
- Undertook foundational AI training through an online self-paced course when AI products were first deployed in the trust dermatology department. This was accompanied by product-specific training led by the ICS Embedder team.
- Applied for a year out of training and was seconded to a digital health fellowship with the ICS AI MDT. During this year, gained necessary experience to complete a PG dip in digital health technologies before returning to complete CCT.
- Applied for a Digital Clinical Consultant post and continues to work in a combined role split between clinical work and working in the ICS AI MDT. Continually updates knowledge through open access digital training courses.

Embedder *Persona 1*

Role

Clinical associate specialist in renal medicine & Digital Health - Nymouth ICS

AI responsibilities

Works as part of the AI MDT at Nymouth ICS alongside work as a renal clinician. Undertakes clinical evaluation of AI technologies including running prospective clinical trials of AI products. Ensures AI technologies are appropriately integrated into clinical workflows. Conducts ongoing clinical surveillance of live technologies within the trust. Produces and delivers clinician-facing product-specific AI educational material.

Education journey

- Undergraduate medical degree with modules on digital health technology and clinical use.
- During foundation years, had a four-month digital health placement working within an ICS AI MDT. Undertook extended joint digital/clinical medical training programme with time split between clinical work and time spent working within the ICS AI MDT. This included collaborative work with industry partners to develop skills in clinical validation and clinical informatics.
- Achieved a set of competencies through this training programme counting towards a PG diploma in clinical informatics and data science supplemented by additional study on a remote learning platform.

Embedder *Persona 2*

Role

Clinical Scientist: Clinical informatics - Nymouth ICS

AI responsibilities

Works as part of the Embedder team at Nymouth ICS. Undertakes evaluation of AI technologies including running local validation using ICS patient data and clinical trials of AI products. Ensures AI technologies are appropriately integrated into existing software and data systems. Conducts ongoing clinical surveillance of live technologies within the trust.

Education journey

- Undertook a clinical engineering apprenticeship as a school leaver. Qualified as a Healthcare Science Practitioner via the in-service Practitioner Training Programme (PTP).
- Via the equivalence progression in-service training route, completed the Scientific Training Programme (STP) in clinical bioinformatics, including a foundational AI education programme and specialised modules that covered requirements for Embedders.
- After training at two other trusts, applied for a role within Nymouth ICS. Continually updates training through open access digital training courses to gain the skills required for each AI project in the trust.

User *Persona 1*

Role

A&E triage nurse - Nymouth ICS

AI responsibilities

Triages patients, attending A&E assisted with an AI triage tool. Weighs up triage information for AI against other clinical information and acts appropriately when the AI assessment contradicts other clinical intuition. Flags safety concerns when AI-derived predictions are inconsistent with clinical expectations

Education journey

- Worked as a triage nurse at Nymouth ICS for several years.
- Consulted by Embedders about the introduction of a new AI triage technology.
- Undertook foundational AI education programme on an online platform.
- Worked with ICS AI MDT to design a safe and effective workflow integration for the triage product.
- Undertook product-specific education for the triage product lead by the ICS AI MDT and continues to attend refresher sessions as the product is updated.

User *Persona 2*

Role

Consultant radiologist - Nymouth ICS

AI responsibilities

Uses AI tools including tools to triage the reporting worklist and tools to support clinical decision making and imaging interpretation for radiology reporting. Flags safety concerns when AI-derived predictions are inconsistent with clinical expectations. Supports clinical audit for ongoing monitoring of AI tools. Participates in user research lead by product developers to inform improvements and updates to AI products.

Education journey

- Undergraduate degree in biology followed by 4-year part-time occupational therapy degree programme.
- After working for several years as an occupation therapist in the NHS, completed medical training through a Medical Doctor Degree Apprenticeship, foundation programme and radiology specialist training.
- As a consultant, undertook foundational AI training through an online self-paced course.
- Participated in product-specific training led by the ICS Embedder team when each radiology AI product was introduced.
- Undertook ongoing product-specific education as AI products are updated.

User *Persona 3*

Role

Practice manager - Holpot Hill GP practice

AI responsibilities

Manages and analyses insights from AI products used in the practice. Aware of safety reporting processes and back up pathways if the AI fails.

Education journey

- Worked as a practice manager at Holpot Hill practice for 8 years.
- When the PCN decided to collectively implement AI solutions to improve patient appointment booking, all staff were supported to undertake the foundational AI education course using the self-paced online course on the NHS learning platform.
- Undertook product specific training on the AI product deployed in the PCN.

Chapter 4: Workforce Transformation

As discussed in the **first report,**[1] the safe, efficient, and effective implementation of AI technologies in healthcare settings will involve strategic, organisational, and cultural considerations. A key insight of the report involves the need for workforce transformation through developing specialised roles and teams, supported by resourcing and training opportunities.

This chapter considers how novel team structures, the recruitment, training and retaining of individuals with specialist AI skills, and new leadership roles can support health settings to deploy AI technologies.

Workforce transformation, as defined by HEE, is a process to improve the recruitment, retainment, deployment, development and ongoing support of the healthcare workforce, to meet the growing and changing needs of local populations – ensuring high quality care for the patients of today and the future.

Workforce transformation efforts to support AI-related education and training can be grouped against the five enablers of the HEE Star framework,[6] as illustrated in **Figure 5**.

Figure 5: Workforce transformation to support AI-related education

Supply

- Establish clear job roles and career pathways for digital, data and technology specialists (see **section 4.2.1**)
- Expand the specialist DDaT data family and clinical informatics workforce through targeted recruitment, increased education and training opportunities, competitive renumeration and flexible equivalence pathways for those with skills from experience outside the NHS (**sections 4.2.1** and **4.2.2**)
- Support professionalisation and accreditation of the DDaT data family and clinical informatics workforce through recognised and trustworthy national bodies (**section 4.2.1**)

Upskilling

- Maximise the potential of the workforce through recognised and accredited digital career and education pathways (**section 4.2.1**)
- Support ongoing CPD (Continuing Professional Development) frameworks for development and validation of digital professionals (**section 4.2.1**)
- Provide protected education time for digital skill development supported by flexible hybrid training pathways for digital specialist clinicians (**section 4.2.1**)
- Provide equitable access to training and support, including special efforts to engage and support the digitally unengaged or unconvinced (**section 4.2.1**)

New roles

- Identify gaps that may be filled by development or implementation of new roles (**section 4.2.1**)

New ways of working

- Establish and support AI multi-disciplinary teams (MDTs) involving clinical and technical roles to lead the evaluation, deployment and product-specific user training for AI technologies. A diverse team and a flat organisational structure should be encouraged to avoid hierarchy and minimise bias (**section 4.1**)
- Through innovative placements and recruitment, promote an integrated workforce that creates new relationships and networks and a working environment that embraces intrapreneurship and collaboration (**section 4.2.1**)

Leadership

- Develop a new cadre of digital leadership roles with recognition of the value of specialist skills at a senior level for individuals with DDaT data and clinical informatics skills (**section 4.2.3**)
- Set out clear training pathways and career trajectories to achieve a specific set of competencies required for digital leadership (**section 4.2.3**).

These elements can complement the educational and training pathways suggested in **Chapter 3**.

Specific considerations when developing Integrated Care System (ICS) workforce plans can include:

- establishment of AI multidisciplinary teams (MDTs)
- development of a plan to increase the digital, data and technical (DDaT) data family workforce to meet future demand. This can include new clinical informatics specialist roles, supported training opportunities, upskilling existing staff into technical roles and joint digital/clinical training opportunities for clinical staff. If deemed necessary, it could also include routes for external expertise to be brought into the healthcare sector
- creation of senior (non-managerial) technical roles with expert AI-related knowledge and skills
- expansion of professional digital leadership positions to lead AI development and deployment.

4.1 AI multi-disciplinary teams (MDTs)

Interviewees for this research noted that specialised AI multi-disciplinary teams (MDTs), which could exist across or within NHS organisations, are a significant factor in the successful adoption of AI technologies. This aligns with HEE's broader strategic goal to support the expansion and development of MDTs.[17]

AI-specific MDTs can comprise of a mix of individuals like specialist clinicians, information technology and governance specialists, clinical domain experts, data scientists, and software engineers. These teams can be further strengthened by data security experts, and regulatory and clinical safety specialists with advanced AI knowledge and skills.

It is critical that AI MDTs are sufficiently diverse and consider inputs and feedback from other experts and patients. Processes to involve stakeholder and the public in the development and implementation of AI technologies, can include participatory assessments of their potential economic, social and environmental impacts conducted as part of algorithmic impact assessments.[41] Diversity in teams who develop and deploy AI has been shown to mitigate the risk of bias and unfairness, leading to more ethical and safer AI products and implementations.[18]

Interviewees highlighted that successful AI MDTs involve sharing of knowledge across disciplines and development of common objectives to address challenges when implementing and monitoring AI technologies. This concept is supported by findings of the Topol Review, which noted that the 'teams required to adopt technology-enabled change are likely to be non-hierarchical, self-organising, multi-disciplinary teams in which colleagues have equal status and responsibility.'[3]

Interviewees also noted that AI MDTs can lead the evaluation, implementation and ongoing monitoring of AI technologies, as well as advise and assist individuals and project teams responsible for AI procurement decisions (primarily within the Driver archetype).

Box 4 provides a list of existing and potential responsibilities for AI MDTs, as suggested by this research's interviewees, while **Box 5** details how these teams can operate in a fictional example.

Box 4. AI MDT responsibilities

The responsibilities of AI MDTs could include:

- Drive development of novel AI solutions or co-create AI technologies with industry innovators
- Consider the needs and views of stakeholders and patients across diverse backgrounds, and seek to involve other experts and members of the public when developing AI technologies
- Co-ordinate engagement with industry innovators and act as a conduit between the two sectors
- Facilitate the introduction of AI technologies including technical integration, systems change management and education of users
- Lead the ethical governance and implementation of AI technologies at their settings
- Evaluate potential AI technologies to assess their suitability for local deployment, including the need for local validation, prospective clinical studies, and assessing technical requirements
- Ensure clinical safety, manage the reporting process for possible safety incidents and establish appropriate back up processes
- Undertake ongoing post-deployment monitoring, surveillance and audits of AI technologies to ensure they continue to perform safely and effectively
- Evaluate the impact of AI technologies on clinical pathways, including review process efficiencies and patient outcomes
- Design, deliver and continually update product-specific user education

Box 5: AI MDT – Fictional case study

This fictional case study is based on an ICS team working to co-create an imaging-based AI technology with an industry innovator within a healthcare setting. It complements the fictional case study presented in **Box 2**.

The aim of this case study is to outline the types of roles and responsibilities of individuals within the AI MDT team, and their relation to the archetypes discussed in this report. It should only be considered as an illustrative example rather than a fixed structure or blueprint as AI MDT size, structure and roles will vary depending on needs, products and local factors.

The AI MDT should represent all teams working for commissioning, developing, and implementing an AI technology, as well as the full range of its users. The team should be diverse in terms of demographics, levels of seniority, and familiarity with digital health to ensure fairness for both staff and patients.

All product and organisation names used in this case study are fictional.

Summary: A chest X-ray triaging AI product (tri-X) is co-designed between the Linchester ICS and an industry innovator, Triadix. The technology is designed to help manage the radiology workflow by prioritising chest X-rays for reporting by radiologists. The project AI MDT comprises key individuals involved with or affected by the development and implementation of tri-X.

ICS Digital transformation lead
Driver

- Oversee the work of the AI MDT, championing their role and advocating for appropriate funding and resourcing of the team
- Ensure the appropriateness of the AI solution to ICS needs and clinical workflows
- Commission Triadix as a commercial partner to co-create tri-X and manage their contractual relationship, including intellectual property, data sharing agreement and commercial commissioning agreements for the wider roll out of tri-X
- Ensure that appropriate regulatory standards are being adhered to when creating tri-X and the product development aligns with appropriate guidelines

Radiology business manager
Driver

- Consider impact of tri-X on finance, human resources, training and sustainability
- Help to define business case and outcome measures that will address real world system benefits to the ICS radiology service
- Conduct service level risk assessment, and oversee service continuity and decommissioning planning

Clinical specialist - Radiology consultant
Creator / User

- Define clinical scope of the product and advise on workflow integration plan at the design stage, including representation of a diverse range of users
- Conduct clinical risk assessment and develop mitigation plan
- Review validation performance and prospective clinical studies of tri-X
- Advise on systems change processes involved in the introduction of tri-X
- Support creation and delivery of product-specific user education for tri-X to ICS radiologists alongside Embedder colleagues
- Use tri-X in clinical work

Clinical product manager
Creator

- Undertake problem discovery sessions with stakeholders, map out workflows and explore the clinical issue to be solved by tri-X
- Define the scope of use and requirements for tri-X
- Liaise with clinical experts including ICS radiologists to ensure that the product is clinically robust and is integrated strategically into clinical workflows

- Co-create tri-X with users. Conduct regular user research sessions to get feedback on how to improve the product and add value to users
- Ensure tri-X aligns with safety and regulatory standards, working closely with Linchester ICS safety and regulatory team from the outset
- Coordinate with ICS data science teams and clinical specialists to conduct prospective clinical studies of tri-X, in line with Linchester ICS requirements and national evidence for efficacy

Lead project data scientist
Creator / Embedder

- Oversee the ICS data and clinical science team working on technical aspects of creation, validation and embedding of tri-X, including:
  - Analysis of the data set available to address the problem, evaluating the data for representativeness, potential bias and generalisability and ensuring it is of appropriate quality
  - Working alongside Triadix data scientists and software engineers to create, test and improve the tri-X AI model, iterating until accepted accuracy and safety levels are reached using internal test data
  - Overseeing validation of the final algorithm using internal and external validation data sets, as well as conducting prospective clinical evaluation studies in collaboration with users and Triadix team
  - Assessing the regulatory compliance of tri-X
  - Conducting post-market follow up to assess and monitor performance, and act upon any model drift
  - Creating and delivering product-specific user education for tri-X alongside clinical MDT colleagues

Clinical safety officer
Embedder

- Conduct a clinical safety review and risk assessment of tri-X

- Ensure there are appropriate protocols in place for systems failure, fall-back workflows, reporting errors and on-going monitoring
- Consider mitigation plan for potential risks of deskilling, if relevant

IT officer
Embedder

- Lead the technical implementation of tri-X including systems integration, data and cyber security, data storage, system robustness and availability
- Provide ongoing advice and support for users of tri-X

IG officer
Embedder

- Lead integration with existing information governance processes or development of new processes as needed for the tri-X project, providing guidance from early in the project ideation stage through to deployment

AI MDTs will likely be required at different levels within the NHS. For example, project-level MDTs might manage the deployment of specific AI technologies within individual healthcare settings. These teams could be supported by organisational-level AI MDTs acting as a shared resource and source of advice and guidance across multiple sites (such as an Integrated Care System, primary care network or large hospital trust).

The Goldacre Review suggests identifying 'Data Pioneer' analytics teams in Integrated Care Systems and trusts with strong existing skills in analytics, informatics, and software engineering. These can be an example of organisational-level AI MDTs, and could provide a framework for other team structures by making their methods visible to the wider community and providing open documentation of their work for learning.[4]

Interviewees noted that the development of organisational-level MDTs will need to coincide with structural changes in the NHS to allow for sharing of resources and available capacities at each healthcare site.

4.2 Specialist AI skills within the NHS

As noted in **section 1.1**, specialist skills and roles that relate to the Creator and Embedder archetypes can be described differently across entities, initiatives and research reports. These include: 'digital, data and technology (DDaT) specialists', 'data scientists', 'data analysts', 'data engineers', 'clinical scientists', 'clinical informaticians', 'clinical bioinformaticians', 'digital professionals', and 'AI professionals'. This variance highlights the need for further work to reach consensus on the terminology and clarify links across these roles.

Feedback from the interviews conducted for this research suggests that many healthcare settings have significant gaps in relation to the skills and capabilities associated with the Creator and Embedder archetypes.

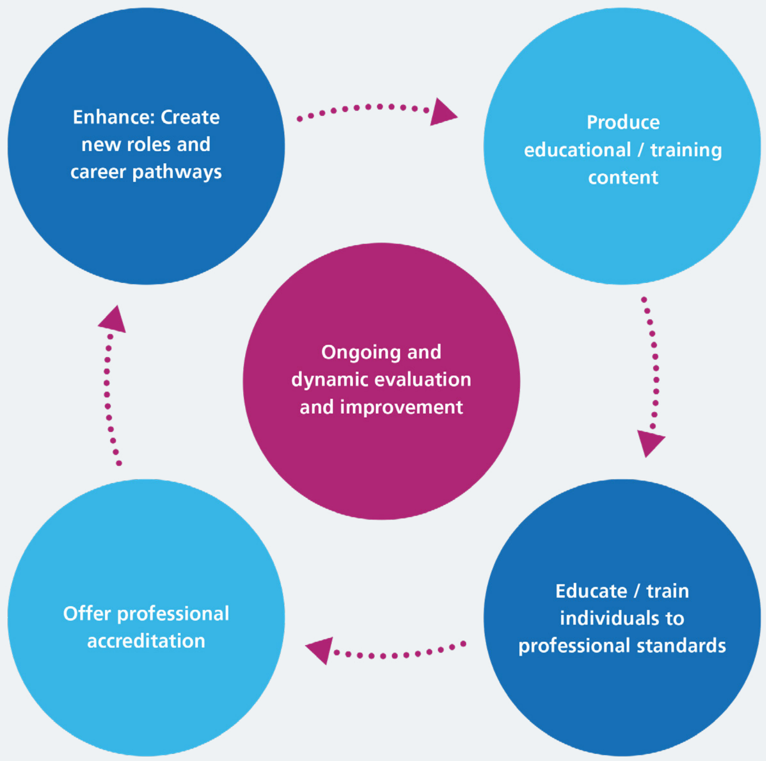
Aspects of developing and deploying AI technologies may require increased workload when collecting, managing and processing data. The NHS may need to employ and train professionals to ensure appropriate resourcing or address any resource gaps, including the projected need for 11,953 more clinical informatics professionals by 2030 outlined in HEE's 'Data driven healthcare in 2030' report. The report recommends a 'focus on the supply factors affecting the NHS digital technology and informatics workforce and developing an action plan to address the need for an increase in staffing levels'. The report highlights that 'the level of investments required in developing a specialised AI workforce will be significant, and the NHS will face recruitment and retention challenges in a competitive labour market'.[7]

Interviewees for this research observed that, given the current gap, capabilities associated with the Creator and Embedder archetypes are provided through collaborative projects with industry innovators or academia. This suggests that, in the short term, specialist technical roles like data scientists and AI engineers may need to be recruited or contracted from outside the NHS. To do so, healthcare settings will need to compete with industry for technically skilled staff, and build environments that enable these individuals to apply their expertise rapidly and with real-world impact on patient care.

Interviewees also noted that the adoption of some AI technologies may lead to re-deployment of existing resources, either as a result of automating human tasks or by shifting volumes of work to different parts of service delivery models. Due to these changes, some professionals may require new data science skills. This will need to be supported and planned due to significant perceived challenges, especially for smaller healthcare settings.

In the long term, developing and sustaining specialists AI skills will require development of appropriate education, accreditation and career pathways as illustrated in **Figure 6**, and discussed in the following subsections. This should be supported by constant and dynamic evaluation and improvement of educational efforts, professional accreditation routes and career pathways.

Figure 6: Workforce development cycle



The 'Data saves lives' strategy outlines existing efforts to build analytical and data science capabilities, including building the profile of data and analysis as a profession through competency frameworks, networks, training, career opportunities and status, and work with the Developing Data and Analysis as a Profession Board.[11]

4.2.1 Training and professionalisation of specialist AI skills

Training for clinical informatics roles (associated with Embedder and Creator archetypes)

Developing Creator and Embedder capabilities within the NHS will require establishing new training pathways and expanding existing training programmes for new specialist roles and positions (such as clinical scientists). The aim would be to develop specialists with both clinical and AI-related expertise.

A few training programmes for individuals with specialist skills required to undertake Embedder and Creator roles currently exist within the NHS but have limited training numbers. For example, the Scientist Training Programme (STP) by the National School of Healthcare Science (NSHCS), is a three-year programme of work-based learning, supported by a university accredited master's degree that covers roles for informatics in healthcare science, including Clinical Bioinformatics Genomics, Clinical Informatics (formerly known as Bioinformatics Health Informatics) and Clinical Scientific Computing (formerly known as Bioinformatics Physical Science).[21]

In 2021, there were only six training posts available for informatics roles in genomics, seven in health informatics, and four in physical sciences (the sub-specialisms relevant to the AI Embedder archetype).[22] Training programme numbers will need to be significantly expanded to meet the forecasted need for clinical informatics professionals if this cohort is expected to support adopting AI technologies at scale.

Upskilling

It may also be appropriate to upskill and retrain existing professionals with clinical informatics skills to move into new job roles. Further to the STP, the Academy for Healthcare Science (AHCS), a joint initiative of the UK Health Departments and the professional bodies across Healthcare Science, provides an equivalence route for existing NHS staff to acquire the title of clinical informatician through apprenticeships in NHS trusts or training by non-NHS organisations.[23] Further training routes that allow for transfer of skills from outside the NHS could also be considered. Interviewees for this research noted that transferring skills should be facilitative rather than restrictive, supported with pathways to obtain the required competencies rather than relying on onerous paperwork to prove skills.

Digital and AI specialist clinicians

AI MDTs will require clinicians with advanced AI knowledge, and both clinical and technical expertise. These individuals will need to be able to communicate effectively with technical specialists like data scientists, liaise with clinical teams, promote safety and ensure products deliver real clinical impact.

Clear job roles and career pathways should be established for digital and AI specialist clinicians. HEE's 'Data driven healthcare in 2030' report recommends '*developing standardised job roles for multi-professional clinicians, including clinician informaticians, to address the workforce demand anticipated across the depth and breadth of clinical informatics*'.[7]

Interviewees for this research reported that at present, clinicians can develop skills and knowledge related to digital health, data science and AI only by pursuing self-directed, voluntary learning in their own time or taking time out of training to complete additional qualifications or work for industry organisations outside the NHS in order to gain skills and experience. They reported that digital and data-related topics are generally not included in undergraduate or postgraduate curricula, and are often not supported through study budgets or protected time.

Clinicians at all stages of their career should actively be encouraged to develop skills in DDaT, particularly data and informatics skills, including AI. This could be accomplished through inclusion of digital topics in undergraduate and postgraduate curricula, by offering protected time and funding for digital skills training throughout the clinical workforce and by creating joint digital and clinical training programmes that combine clinical work with roles within AI MDTs and/or placements in academia or industry.

HEE has partnered with the University of Manchester to develop a 'Clinical Data Science' programme due for launch in September 2023, which aims to increase clinician awareness of data science accredited with a postgraduate certificate. Similar education material could be considered for AI, and made accessible to a wider range of clinicians across the NHS.

Funded by HEE, the London Medical Imaging and AI Centre for Value Based Healthcare has launched fellowships in clinical AI.[24] The year-long fellowship programme offers trainees the chance to develop AI-related skills for two days a week (or 40 per cent time equivalent) alongside less than full-time training. The fellows undertake a programme of teaching aligned with the Clinical AI Curriculum developed by Guy's & St Thomas' Department of Medical Physics whilst also contributing to immersive AI projects in live hospital workflows, supervised by experts in clinical AI.

Flexible portfolio training (FPT) is a pilot initiative within higher specialty training offered by HEE and the Royal College of Physicians that protects one day a week (or 20 per cent time equivalent) for professional development without impact on the length of training.[25] Clinical informatics is one of four pathways offered within FPT. Trainees on the clinical informatics pathway develop capabilities in information governance and security, system use and clinician safety, digital communication assessment, information and knowledge management, patient empowerment and emerging technologies.

Collaborative training with academia and industry

Interviewees for this research noted the importance of collaboration between healthcare settings, academia and industry innovators to train and employ individuals with Embedder and Creator skills.

HEE's 'The future of clinical bioinformaticians in the NHS' report recommended to 'set out a proposed model of how to involve external partners in the commissioning and training of clinical bioinformaticians by looking at research departments'.[8] Reciprocal fellowship placements with industry are being considered as part of the Clinical Scientist STP programme.

HEE has set up an industry roundtable and is exploring the potential for collaborative training opportunities with industry innovators, including members of the Association of British HealthTech Industries, the Association of the British Pharmaceutical Industry, Tech UK, Health Tech Alliance, Imagine Talent and the Organisation for the Review of Care and Health Applications. As an example, the Imagine talent collaborative community explores the future of talent for a digital age and are trialling a digital talent model.[26] This involves giving an opportunity to data scientists from various organisations (including at NHS and HEE) to work across sectors and organisations to build their expertise and experience.

HEE has also established the Health Innovation Placement (HIP) pilot[27] as part of the Digital Readiness Education Programme.[28] It provides leaders with an opportunity to develop through exposure with start-ups / small-medium organisations (SMEs) and to work on the development of a technological solution to a specific NHS problem.

Informatics Skills Development Networks (ISDNs)

HEE has supported the creation of eight regional ISDNs across England, which are based on the existing Finance and Procurement Skills Development Networks models.[29] The ISDNs aim to support the training and career development of digital professionals at a regional level by providing educational programmes, networking opportunities and acting as an interface with key professional bodies including the Faculty of Clinical Informatics (FCI), British Computer Society (BCS), College of Healthcare Information Management Executives (CHIME), Federation of Informatics Professionals (FEDIP) and Association of professional healthcare Analysts (AphA).

ISDNs could play a role in co-ordinating key components of **Figure 6**'s workforce development cycle, including the delivery of education, accreditation with professional bodies and guiding the creation of appropriate job roles and career pathways within the region.

Professionalisation and accreditation

Professionalisation of the DDaT data family and clinical informatics workforce, overseen by a recognised governing body, would support the development and recognition of these roles. This could include formal qualifications such as post-graduate certificates, diplomas, and degrees, alongside more flexible educational pathways, competency frameworks and the creation of recognised job roles.

Current related initiatives include the NHSE Digital Workforce Programme within the System CIO/Director of Levelling-up Directorate, and the development and testing of a National Competency Framework for Data Professionals in Health and Care that will include a set of core competencies for health and care data professionals.[42]

Several organisations have been supporting broader work in the professionalisation of the data and informatics workforce including the FCI, FEDIP and AphA. Cross-government initiatives like the Digital, Data and Technology (DDaT) Profession Capability Framework[30] can inform approaches in healthcare.

4.2.2 Rewarding and retaining individuals with specialist skills

HEE's 'The future of clinical bioinformaticians in the NHS' notes that retention of this cohort has been challenging, despite the small numbers of clinical bioinformaticians trained each year and growing demand for their skills within the NHS.[8] The major factors affecting the retention and utilisation of clinical bioinformaticians include having to continuously deal with undemanding and conventional tasks, combined with a perceived lack of promotion opportunities. As the report suggests '*The NHS clinical bioinformaticians want to stay only if they can do the work that they are trained for*.'[8]

The current levels of renumeration for specialist skills within healthcare settings may be limiting external interest in these roles. Data scientists and data analysts in the private sector who are proficient in machine learning and AI can expect to earn more than twice the salary of NHS analyst roles.[4] The Agenda for Change pay scale framework[31] currently limits the salaries of data science professionals as they are classified as 'administrative/clerical' staff. As suggested in the 'Data driven healthcare in 2030' report '*the financial reward structures for the NHS digital technology and health informatics workforce will need to be reviewed with particular attention given to the competitiveness of the labour market in affecting recruitment and retention of staff in the NHS*'.[7] This was re-iterated in the Goldacre Review, stating that '*the NHS must stop expecting to pay highly skilled technical staff in data science and software development on salary scales devised for low and intermediate level IT technical support.*' It recommended the implementation of '*competitive remuneration packages*' for technical skills that '*reflects market value*'.[4]

Remuneration may not be the most important consideration to attract and retain individuals with specialist skills. Perhaps surprisingly, 'The future of clinical bioinformaticians in the NHS' report notes that '*income had not been an essential factor for the career choices of the NHS clinical bioinformaticians*'. The report suggests that clinician bioinformaticians find current wages acceptable and appreciate the additional benefits, such as the NHS pension, holiday entitlement, and maternity/paternity leave. Amongst the bioinformaticians who had left the NHS, most did not cite income as being a factor in changing jobs.[8]

The report also notes that, currently, there are few individuals with clinical bioinformatics skills in relatively senior roles. Consequently, these roles are not well represented in senior decision-making processes, which may have been preventing clinical bioinformaticians from effectively conveying their needs to the management of their trusts.[8]

These insights suggest that other factors affecting retention like opportunities for professional development, and recognition of the value of clinical bioinformaticians at a senior level are important and need to be considered.

4.2.3 Digital leadership roles

Interviewees for this research noted that some health settings have already created senior roles to oversee the deployment of AI technologies. An example is the role of Clinical Informatics Lead responsible for providing and leading development of AI knowledge and skills, including acting as a mentor for other senior leaders, and overseeing implementation of AI technologies across their institution, with assistance from clinical leads at each unit.

Other specialist senior clinical informatics roles within the NHS include Chief Clinical Information Officers (CCIO) and Chief Nursing Information Officers (CNIO). There have been some developments in setting standards for these roles; for example, the Faculty of Clinical informatics have published a model job description for CCIOs[32] and regional ISDNs have set up CCIO special interest groups (SIGs). However, further professionalisation of these roles should be considered, including the creation of joint clinical digital training pathways with protected time spent in digital roles. This should be accompanied by clear career trajectories with support in achieving a specific set of competencies required for digital clinical leadership positions.

The 'Data driven healthcare in 2030' report sketches a new cadre of professional digital leaders to drive forward the adoption of AI and data driven technologies, including CCIOs and CNIOs, and newer positions in the C (chief) suite like Chief Analytical Officers, Chief Data Officers and Chief Knowledge Officers. These will have a vital role in managing and setting the strategic direction for digital technology and health informatics in NHS organisations.[7]

The Goldacre Review also supports the creation of new leadership roles, including a recommendation to '*create very senior strategic leadership roles for developers, data architects and data scientists.*'[4] These positions should allow for career progression into senior technical roles as well as management roles. They will need to be supported by clear and flexible training pathways and career trajectories to achieve the specific set of competencies required for digital leadership.

Examples include:

- In addition to the STP programme, the NSHCS provides a pathway for clinical bioinformaticians to progress into more senior roles in the NHS through the Higher Specialist Scientist Training (HSST) programme. This five-year programme supported by a Doctoral level academic award is designed to prepare clinical bioinformaticians to apply to become consultant clinical scientists in the NHS.[44]
- HEE has established the Digital Health Leadership Programme. The programme is a 12-month fully accredited Postgraduate Diploma in Digital Health Leadership delivered by Imperial College London along with The University of Edinburgh and Health Data Research UK. It is directed at individuals with demonstrable experience (typically three years minimum) of implementing practical digital transformational change within an organisation and/ or wider health and care system.[45]

Expanding these initiatives and providing additional opportunities, career pathways and development programmes for digital leaders may be required to support the creation of new leadership roles.

4.3 The risk of deskilling

When considering workforce transformation in relation to AI technologies, it is important to address the risk of deskilling[33] of the clinical workforce due to reliance on AI technologies[34] for tasks previously undertaken by clinicians.

Deskilling could affect non-experts, who may defer to AI when completing tasks outside of their area of expertise, as well as experts, who may be unable to maintain and enhance their own clinical judgement skills and confidence if they come to depend on AI technologies.

The risk of deskilling should be considered when AI technologies are deployed in healthcare settings, including through taking appropriate actions to safeguard clinical expertise.[35] This is likely to depend on careful AI product design, such as considering the way in which information is displayed to users. It will also depend on cautious integration of products into clinical pathways; for example, considering when AI technologies are used in a workflow and whether clinicians are 'blinded' to AI outputs when making their own clinical assessments. It may be appropriate that a proportion of cases are handled manually both to retain skills and to allow on-going monitoring of the AI against human performance on current clinical data.

It will be important that all workforce archetypes are aware of the risk of deskilling so it can be mitigated at all levels. It will be essential for Drivers to understand this risk so they can ensure pathways and procedures are in place within local settings to monitor and minimise deskilling.

Conclusion: Looking Ahead

The educational challenge

Educating the healthcare workforce to develop, implement and use AI effectively and safely is a multidimensional challenge, involving undergraduate education, postgraduate training, and lifelong learning. This report has presented an overview of a suggested approach and key educational requirements to develop confidence in AI-driven technologies across the healthcare workforce.

At a strategic level, this report can inform how HEE, educational and training providers and educators of healthcare workers can plan, resource, develop and deliver education to equip the workforce with the necessary AI knowledge, skills and capabilities.

Whilst the educational requirements in this report are not a detailed curriculum in themselves, they are intended to inform curriculum development for foundational AI education and advanced content for specific archetypes, and guide learning content for continuing education of qualified professionals throughout the workforce.

Development of a foundational curriculum and the associated content will be an urgent priority.

Educational efforts should be flexible, and include a solid foundation for developing AI-related knowledge as well as personalised advanced elements to fit the needs of individuals in specific roles.

The requirements can assist providers and educators in creating content for their educational and training offerings. They are presented by workforce archetype to allow tailoring of educational offerings according to the breadth of roles that healthcare professionals will take in the development, implementation and use of AI and other data-driven technologies.

The wider context

Interviewees for this research noted that the success of AI-related education and training will be dependent on wider requirements for transformation and change towards a digital-ready workforce, including the development and education of DDaT data and clinical informatics teams within NHS organisations, including specialised high-level leadership roles. These were explored in detail in **Chapter 4**.

A key part of this report's suggested educational approach (**section 3.1**), involves continuation of the broader efforts to enable change and innovation in healthcare settings, as well as efforts to advance digital skills and capabilities within the workforce as important foundations for specific education and training in AI. When considering wider digital health and data-driven technology education, it may be appropriate to apply the approach this report has taken to structure the workforce into archetypes.

Digital infrastructure and organisational digital maturity are also key enablers of transformation through data-science and AI, without which large-scale adoption of AI technologies will not be possible.

These broader efforts should be considered a priority that will support educational and training offerings to develop healthcare workers' confidence in AI.

What happens next?

As suggested, the educational requirements identified in this report will need to be adopted through change to educational curricula and the provision of AI-specific content, alongside concrete changes to roles and career paths for specialist AI healthcare workers. The next steps to achieve these can include:

Educational priorities

- **Produce foundational AI educational content.** Concerns about the lack of basic awareness and knowledge about AI amongst most healthcare workers highlight the urgent need for an accessible foundational AI education programme delivered in a scalable format.
- **Produce flexible post-qualification educational resources.** The diversity of skills, roles and educational needs in the existing workforce demands a flexible approach to delivering continuing professional

development education. HEE, in collaboration with other partners in the public sector, academic and industry, can work towards producing and collating materials that can be accessed online and potentially personalised through self-assessment. These can be organised according to this report's archetypes, and the individual's experiences and interests, and could be available through a centralised online learning hub and/or other platforms like the NHS Digital Academy, the NHS Learning Hub, and AnalystX.[43] Curated education journeys will be required to guide learners to the appropriate information to meet their AI learning needs.

- **Develop product-specific training.** A collaborative effort between industry innovators and NHS staff in health settings will enable product-specific training to better reflect the local workflows and clinical settings and meet NHS user needs. The product specific training and a strategy for its use should be present from procurement through to workflow integration.

Next steps by workforce archetype

- **Shapers.** Shapers will largely work in national organisations that have traditionally been involved in regulation or guidance for healthcare, including within and beyond the remit of HEE and NHS. Both foundational education in AI technologies and more advanced training regarding the governance, validation and implementation of AI technologies would improve Shapers' abilities to translate their activities into the domain of data-driven algorithms and AI. This can include a healthcare-focussed educational offering for Shapers in national roles.

- **Drivers.** Interviewees for this research highlighted challenges relating to information technology, interoperability, and data governance as major barriers to deploying AI technologies in their settings. Prioritising education for the Driver archetype to support them in making the right strategic and governance decisions relating to AI may help to address these challenges. This can include development of specific educational resources or programmes for senior leaders to enable them to make informed decisions around specific technologies and prepare their organisations for deployment of AI technologies. It should also include engagement and support of ICS leaders to develop workforce plans that ensure appropriate digital, data and technology skills are being developed within the workforce.

- **Creators and Embedders.** Establishing and expanding training opportunities for Creators and Embedders should be considered a priority to fill the significant skill gaps highlighted by this research relating to DDaT data family and clinical informatics skills. These skills are vital not only to support creation and implementation of AI, but also for ongoing monitoring, assurance and audit of AI technologies. New opportunities should be established alongside efforts to upskill existing professionals with digital and data skills and establish flexible training opportunities for digital specialist clinicians. These efforts can be supported by the professionalisation and accreditation of these roles, the development of AI MDT teams, and the establishment of clear professional development and career pathways.

- **Users.** Development of user-related education and training will rely on engagement with undergraduate and postgraduate education providers. HEE does not directly provide education to healthcare professionals in training, but works with organisations like the Royal Colleges, national schools, and universities to advise on educational priorities. Further work is needed to work with these organisations and incorporate AI education into undergraduate and postgraduate curricula and to ensure these are aligned with other areas of education reform.

Many of these identified efforts are already underway, being led by Health Education England, the NHS Transformation Directorate, Integrated Care Systems and trusts, and industry innovators.

A forthcoming project, 'Establishing healthcare workers' confidence in AI', will involve engagement with these organisations and relevant groups and sharing of updates on progress being made on these efforts.

Appendix A: Advanced AI education for specific archetypes

This Appendix outlines the key educational and training requirements to develop advanced AI-related knowledge, skills and capabilities, as outlined in **section 3.3**.

These requirements will be additional to the foundational requirements outlined in **section 3.2**. and the requirements for product-specific education in .

The broad aim of the advanced requirements is to develop in-depth understanding of, and skills related to, the subject area, following the taxonomies illustrated in **Figure 4**. These will enable healthcare workers to lead different aspects of the deployment of AI technologies in health settings and advise others.

Interviewees for this research proposed that the need for these advanced requirements should be based on the roles and responsibilities of the healthcare workers (essentially, the workforce archetypes outlined in **Chapter 2**).

Figure A1 presents an overview of how the advanced requirements relate to the workforce archetypes and the factors that influence confidence in AI (see **section 1.2** and the **first report**[1]). The following subsections provide details of these requirements for each archetype.

Figure A1: Workforce archetypes and needs for advanced AI education

Influencing factors	*Archetypes*				
	Shapers	Drivers	Creators	Embedders	Users*
AI literacy			✔	✔	
Governance					
Regulation and standards	✔	✔	✔	✔	
Evaluation and validation	✔	✔	✔	✔	✔
Guidelines	✔	✔	✔	✔	✔
Liability	✔	✔	✔	✔	✔
Implementation					
Strategy and culture	✔	✔			
Technical implementation			✔	✔	
Local validation		✔	✔	✔	
Systems impact	✔	✔	✔	✔	
Clinical Use**					
AI model and product design			✔	✔	✔
Cognitive biases			✔	✔	✔
Interface with patients					✔

*Not all users will require education in these areas, this is discussed in more detail in **section A.5**

**This layer is only relevant to AI used in clinical decision making

The requirements are collective rather than individual. An individual will not always meet all the requirements themselves, but work within a team where others bring advanced knowledge and skills. **Section 4.1** provides further discussion on the development of AI multi-disciplinary teams (MDT).

A.1 Advanced AI education for Shapers

Shaper

Set the direction for AI policy and governance at a national level

Example responsibilities

- Decide on AI policies within healthcare at a national level
- Author and enforce regulation for AI technologies, for professionals creating and using AI and for healthcare settings implementing AI
- Create guidelines for the creation, procurement, deployment and use of AI
- Produce national procurement frameworks for AI technologies
- Guide training of healthcare professionals

Examples of individuals who may take on this archetype role

- NHS leadership and policymaking teams
- Executives at arm's length bodies (ALBs)
- Product regulators
- Regulators of healthcare workers
- Regulators of healthcare settings
- Developers of healthcare technology standards
- Developers of procurement guidelines
- Developers of product development and implementation guidelines
- Developers of clinical guidelines
- Professional educators

Shapers are responsible for making key decisions that contribute to establishing the trustworthiness of AI technologies, through formal means of governance and oversight. For example, they may develop standards for the development and deployment of AI technologies, and set the agenda for the regulation, validation and procurement of AI technologies within health settings.

These responsibilities suggest that Shapers will require advanced leadership skills and knowledge in how AI is governed, as detailed in **Table A1**.

Shapers will also need advanced understanding of some factors related to the implementation of AI technologies. This is to ensure their decisions support and empower other archetypes to facilitate the safe, effective and efficient deployment of AI technologies.

The specific level of expertise required in each of the factors listed in **Table A1** will vary according to Shapers' responsibilities and their organisations. For example, individuals working for regulatory organisations will be expected to have more expert knowledge relating to regulation and standards compared to Shapers working for other organisations.

As noted in the **Conclusion**, the development of education and training offerings for Shapers can be prioritised to support the development of robust foundations for confidence in AI across the workforce.

Table A1: Shapers: Requirements for advanced AI education

In addition to the knowledge requirements outlined in foundational AI education, Shapers will need the following more advanced knowledge and skills.

Taxonomy: • **Knowledge** + **Skill**

Governance

Regulation and standards

- Familiarity with the clinical governance process for AI software as a medical device (SaMD) including clinical audit, clinical risk management, quality assurance and clinical effectiveness
- Familiarity with GDPR applied to healthcare AI products
- Familiarity with NHS digital information standards relating to AI (for example, DCB 0129, DCB 0160)
- Understanding of CE/UKCA marking and methods for obtaining certification
- Understanding of different classes of medical device for AI software under UKCA and the related regulatory requirements
- Understanding of the limitations of CE/UKCA marking, particularly relating to performance and evaluation

+ Capable of engaging with international colleagues to improve alignment of regulation and standards across markets and healthcare systems

Evaluation and validation

- Awareness of testing and validation techniques for different types of AI algorithms and products (for example, hold out set validation or K-fold cross validation)
- Awareness of appropriate methodology for prospective clinical studies of AI technologies
- Awareness of guidelines for AI clinical trials
- Awareness of approaches to model bias measurement and mitigation
- Familiarity with evidence standards for AI products (for example, NICE evidence standards framework)
- Understanding of the role of local model validation and circumstances in which this may be required
- Understanding the need for ongoing monitoring and evaluation requirements for AI technologies after clinical deployment

Guidelines

- Familiarity with AI medical device development guidelines
- Familiarity with AI procurement guidelines

Liability

- Familiarity with f legal frameworks applying to the use of AI in clinical decision making (for example, negligence and product liability)
- Understanding the relevance of liability to implementation and adoption of AI in healthcare

Implementation

Strategy and culture

- Familiarity with how AI technologies can be critically appraised, including the assessment of the impact on patients, financials and systems

- Understanding the challenges of, and opportunities for collaboration and product co-design with industry innovators
- Understanding the principles of digitising, connecting and transforming healthcare services safely and securely
- Understanding of ways that AI technologies may lead to inequitable distributions of patient outcomes or disadvantage certain patients

+ Capable of developing organisational cultures and leaders who support innovation and collaboration
+ Capable of leading and supporting the development of multi-disciplinary teams for development and deployment of AI technologies
+ Capable of leading the development of data science and information governance skills in the NHS workforce
+ Capable of addressing the learning and development needs for NHS staff in relation to AI technologies
+ Proficient in establishing senior leadership buy-in and supporting internal champions for change when introducing AI technologies

Systems impact

- Familiarity with the impact of workflow design on the usability and efficiency of the AI technology
- Understanding the importance of robust systems for detecting, reporting, and managing adverse effects or serious incidents related to AI
- Understanding the difference between algorithm performance and clinical or healthcare economic benefits

+ Capable of supporting interoperability and integration in the context of healthcare technologies
+ Capable of evaluating and addressing the potential impact of AI on workforce and job roles
+ Proficient in supporting systems of effective change management

A.2 Advanced AI education for Drivers

Driver

Champion and lead AI development and deployment at a regional/local level

Example responsibilities

- Set the vision for digital and AI transformation at a regional/local level
- Champion AI technologies, by communicating the value and benefits, as a recognised and trusted leader
- Lead the systems change required to deploy AI technologies effectively
- Lead strategic decision-making related to AI procurement and deployment at a regional/local level
- Implement local AI governance infrastructure to ensure that AI is being deployed safely
- Promote funding and resource allocation for AI at a regional/local level
- Recruit and lead NHS AI multi-disciplinary teams (MDT)

Examples of individuals who may take on this archetype role

- NHS regional leaders
- ICS boards
- Chief Information Officers (CIO)
- Chief Clinical Information Officers (CCIO)
- Project Management Office (PMO) leads
- Digital transformation leads
- Service leads
- Clinical commissioners

As detailed in the **first report**[1], the adoption of AI technologies within health settings will require strong leadership that promotes a culture of innovation. The ideal leader would co-ordinate funding for AI projects, manage change, and build multi-disciplinary teams to lead deployment of AI technologies.

Drivers will play an essential role in leading digital transformation within the NHS and making related strategic decisions, including in relation to AI.

Interviewees for this research noted that Drivers will need to be supported through education and training to understand the urgency and value in their settings' digital transformation with AI and have the skills and knowledge to drive it forward. This includes being intelligent customers for AI technologies, as supported by the recommendation from the Goldacre Review to '*train senior non-analysts and leaders in how to be good customers of data teams*'. Leaders making procurement decisions need the knowledge and understanding to critically appraise AI technologies and ask the right questions to ensure AI is safe, effective and financially viable for their settings (see **Table A3**). A detailed understanding of the governance of AI technologies will assist these decisions.

Drivers will also need to manage systems change when deploying AI technologies. They will need to critically appraise technologies prior to their deployment, and then oversee how they are integrated into clinical workflows, monitored and updated to maintain their performance. Knowledge of the impact of AI systems will therefore be an important aspect of the advanced education of Drivers.

Drivers will be responsible for building AI multi-disciplinary teams (MDTs) to manage the deployment of AI technologies within their settings. They will need to be particularly aware of the value of Embedders with specialist skills in healthcare informatics and data science. The 2021 HEE report 'The future of clinical bioinformaticians in the NHS' highlighted the current lack of understanding of the value of clinical bioinformaticians at the managerial level. Individuals in senior positions are not sufficiently aware of the importance, needs, and capabilities of clinical bioinformaticians.[8]

Drivers will need to understand the roles and responsibilities of Embedders and how to recruit, train support and retain these individuals. This can be achieved through advanced education relating to strategy and culture.

Table A2 lists the suggested advanced educational requirements for Drivers.

Table A2: Drivers: Requirements for advanced AI education

In addition to the knowledge requirements outlined in foundational AI education, Drivers will need the following more advanced knowledge and skills.

Taxonomy: • **Knowledge**
\+ **Skill**

Governance

Regulation and standards

- › › Familiarity with CE/UKCA marking and methods for obtaining certification
- › › Familiarity with different classes of medical device for AI software under UKCA and the related regulatory requirements

- Familiarity with the limitations of CE/UKCA marking, particularly relating to performance and evaluation
- Understanding of the clinical governance process for AI software as a medical device (SaMD) including clinical audit, clinical risk management, quality assurance and clinical effectiveness
- Understanding of GDPR applied to healthcare AI technologies
- Understanding of NHS digital information standards relating to AI (for example, DCB 0129, DCB 0160)
- Understanding of HRA definitions of clinical research and service evaluation as they relate to AI evaluation and implementation, and following the appropriate governance for each

Evaluation and validation

- Awareness of testing and validation methodologies for different types of AI technologies
- Awareness of methodology for prospective clinical studies of AI technologies
- Awareness of guidelines and governance of AI research projects and clinical trials
- Awareness of approaches to model bias measurement and mitigation
- Awareness of potential sources of error and bias resulting from AI validation design
- Familiarity with evidence standards for AI products (for example, NICE evidence standards framework)
- Understanding of the need for ongoing monitoring and evaluation requirements for AI technologies following their deployment

Guidelines

- Understanding of AI procurement guidelines

Liability

- Understanding of legal frameworks applying to the use of AI in healthcare (for example, negligence and product liability)

Implementation

Strategy and culture

- Understanding of the learning and development needs for NHS staff in relation to AI technologies
+ Capable of evaluating the strategic impact of AI technologies – including on patient care, financial and healthcare systems
+ Capable of approaching industry for collaborative problem solving and product co-design
+ Capable of leading digitisation projects to connect and transform healthcare services safely and securely
+ Capable of developing and supporting AI MDTs for AI development and deployment
+ Capable of developing data science and information governance skills in the NHS workforce
+ Proficient in developing an organisational culture that supports innovation and collaboration

Local validation

- Familiarity with ongoing monitoring requirements for AI algorithms
- Understanding of the role of local validation and the circumstances in which this may be required
- Understanding of the skills and expertise required to undertake local validation and ongoing monitoring and how to train and recruit individuals with these skills
- Understanding of the need for algorithmic audit36 when implementing a new data-driven technology

Systems impact

- Familiarity with the impact of workflow design on AI usability and efficiency
- Understanding the importance of robust systems for detecting, reporting, and managing adverse effects or serious incidents related to AI

- Understanding the difference between algorithm performance and clinical or healthcare economic benefit
- Understanding the importance of interoperability and seamless integration in healthcare technology
- Understanding the impact of workflow design on AI product usability and efficiency
- Understanding the risk of AI technology resulting in deskilling of clinical workforce and how product design and workflow integration should be optimised to ensure that these risks are mitigated.

+ Capable of evaluating and addressing the impact of AI technologies in terms of service efficiency, patient outcomes, workforce and job roles
+ Proficient in the application of the principles of effective systems change

When an AI technology is being considered for procurement, certain questions should be asked to ascertain its suitability and performance, the requirements for deployment and the impact of integration into the clinical workflow.

Table A3 provides a comprehensive list of the questions that Drivers will need to have answered, to be confident when procuring AI technologies. It is not necessary for Drivers to understand all the technical details of implementation and AI design, but they should be aware of the need for this information within the AI-MDT, which will include embedders as technical experts.

The questions can be used in addition to the questions outlined in the NHS AI Lab's 'A buyer's guide to AI in health and care',[37] and include further areas of inquiry aligned to the factors that influence confidence in AI identified in our **first report**[1].

Table A3: Drivers: Questions to establish confidence in specific AI technologies.

Governance

Regulation and standards

- Is the AI technology a medical device according to UK regulation? If so, does it have appropriate UKCA/CE marking? What class of medical device has it been designated and is this appropriate?
- What is the manufacturer’s intended use of the product? (including any exclusions or limitations of scope)
- Is it compliant with NHS digital standards (for example, DCB 0129, DCB 0160)?
- Is it compliant with appropriate ISO standards (for example ISO 82304, ISO 13485)?
- Does this technology abide by regulation relating to access and procurement of data (for example, GDPR)?
- Does the technology meet GDPR/ICO/MHRA transparency standards?

Evaluation and validation

- Has this AI technology met appropriate evidence standards in accordance with the NICE evidence standards framework for digital health technologies?
- How has the AI been clinically validated? Has it undergone internal validation, external validation and prospective clinical studies?
- Is there appropriate transparency about the training data set? Is the training data set appropriate for the local context (likely to generalise well)?
- What AI model performance metrics have been used, are they appropriate and are the results acceptable?
- Does the technology require additional local validation due to generalisability concerns or specific local factors?

- What are the ongoing validation and monitoring requirements for this technology once deployed?
- What are the specific risks of bias in model design and training for this technology?
- What steps have been taken to mitigate against these biases? How can they be further mitigated during implementation and local validation?

Guidelines

- What clinical guidelines apply to using this AI technology?
- What are the implications of using this technology outside of the guidelines?

Liability

- Where does liability lie if the AI output is incorrect and leads to patient harm? Is it clear what is considered product failure versus human error in using the product?
- What are the potential legal implications of either using or ignoring an AI output in clinical decision making?

Implementation

Strategy and culture

- What are the strategic advantages of introducing the AI technology? How will it impact clinical outcomes, workflow efficiency, releasing time to care and financial costs?
- Is the AI technology the most effective and efficient solution to address patient and organisational needs, and how does it compare to alternative solutions?
- What are the possible risks associated with the AI technology and how can we account for these?
- Will the AI technology lead to inequitable distribution of patient outcomes or disadvantage any patients? Will it exacerbate existing health inequalities or develop new inequalities?

Technical implementation

- What are the technical requirements for the AI technology? Will the technology integrate with existing IT systems and use open standards or does it need development of new systems?
- What are the requirements for data generation, recording, curation, processing, dissemination, sharing, and use? What are the developer's expectations regarding ongoing data sharing post-deployment to facilitate model iteration and development?
- What IP arrangements are needed?
- What are the risks for data security and privacy? What arrangements are needed for data protection and privacy?
- What levels of staff support and infrastructure are needed for the ongoing technical maintenance and updates of the AI technology?
- What is the developer's approach to ongoing updates and how will this be financed?
- How will product decommissioning be managed with the developer including access and storage of patient data?

Systems impact

- How will the AI technology affect the current workflows and pathways (clinical and administrative)?
- Are there opportunities for more efficient workflows and effective pathways with introducing the AI technology? Is broader redesign needed to take advantage of the technology?
- How can we ensure fairness, transparency and equitable outcomes in the use of this technology?
- What will be required to facilitate the reporting and actioning of safety concerns and adverse event reporting?

Clinical Use

AI model and product design

- In what clinical settings and scenarios is the product appropriate for use? Are there any exclusion criteria or limitations of approval scope?

- How is this technology used in a clinical workflow? Is it autonomous AI or a human-in-the loop system?
- Does the technology show how it has come to a decision (explainable AI)? Has this been validated clinically?
- Does the technology display certainty estimates? Is it clear how these should be interpreted?
- What input data is the model using to make a decision?
- Can the AI system detect and/or reject outlier cases?
- What are the risks of model bias for this technology? Have appropriate steps been taken by the developer to mitigate this?

A.3 Advanced AI education for Creators

Creator

Create AI technologies for use in healthcare settings

Example responsibilities

- Create AI algorithms independently or through collaboration with industry innovators and/or academia
- Align AI algorithm development with appropriate regulation, evidence standards and technical guidelines
- Conduct user research with healthcare professionals
- Test and validate AI algorithms during product development and subsequent releases
- Iterate and improve AI algorithms
- Evaluate AI in terms of performance and clinical impact
- Set up systems for the ongoing monitoring of AI algorithms to assess for any model drift
- Conduct clinical trials of AI algorithms

Examples of individuals who may take on this archetype role

- Specialist digital clinicians
- DDaT data professionals (data analysts, data engineers, data scientists)
- Clinical informatics professionals, including clinical scientists (such as clinical bioinformaticians)
- Software engineers
- NHS AI researchers

Interviewees for this research noted the AI technologies currently deployed in health and care settings are either being purchased 'off the shelf', developed by internal teams, or developed through collaboration with industry innovators.

The Creator archetype includes healthcare workers who are involved during any aspects of the development of AI technologies, including scoping, design or testing. These individuals can represent a variety of clinical and non-clinical professional groups. Medical, scientific and informatics professions are likely to be strongly represented in this archetype and can bring a unique blend of clinical and technical expertise to product design and development.

Due to the demands of their role, Creators will require advanced knowledge of most factors associated with confidence in AI technologies, although as discussed earlier it is not necessary for every individual to possess the full range of knowledge and skills (provided it is represented within the AI MDT; see **section 4.1**) It is likely that clinical and industry team members will require different skills that depend on the nature of each project.

Creators will need to be supported through education and training to understand:

- the impact of AI technologies on clinical workflows and clinical decision making
- user-driven design and workflow integration
- cognitive biases, their impact on assisted clinical decision making and ways to mitigate their impact
- clinical risks and legal responsibilities associated with the implementation of AI technologies in healthcare.

Creators will also need to have a detailed understanding of machine learning and AI as well as the clinical questions to be addressed. They will require an appreciation of the regulatory healthcare landscape around software and medical devices, and the broader healthcare technology ecosystem.

Health settings may need to recruit or train staff with relevant Creator skill sets, such as software engineers and data scientists. This is discussed in detailed in **section 4.2**.

Table A4 lists the suggested advanced educational requirements for Creators.

Table A4: Creators: Requirements for advanced AI education

In addition to the knowledge requirements outlined in foundational AI education, Creators will need the following more advanced knowledge and skills.

Taxonomy: • **Knowledge**
\+ **Skill**

AI literacy

- • Familiarity with the data provenance, quality and structure requirements for developing AI models
- • Familiarity with different project methodologies used for software development (for example, agile, waterfall) and their relative merits
- • Understanding of data-driven problems (for example, classification, regression, generative)
- • Understanding of different types of algorithms, their benefits and limitations (for example, logistic regression, decision trees, support vector machines, random forest, K-means clustering, neural networks, Bayesian approaches)
- • Understanding of neural networks and their common variants (for example, fully connected network, convolutional neural network, recurrent neural network, generative adversarial network)
- • Understanding of learning methodologies (for example, supervised, unsupervised, reinforcement learning, ensemble learning, distributed learning)
- • Understanding of methods for validating AI models (for example, hold out method, cross validation)
- • Understanding of the limitations of trained AI models for prediction and generative tasks, deriving from limitations of the available data sets and the statistical nature of the algorithm
- \+ Capable of coding in languages and tools used for the creation and analysis of AI algorithms (for example, R, Python, Jupyter notebooks)
- \+ Capable of engaging with the appropriate software development methodologies (for example, agile) to meet the needs of a given project

+ Capable of identifying the most appropriate type of algorithm/methodology to solve a given problem
+ Capable of data extraction and wrangling (for example, feature labelling/extraction, dimensionality reduction, normalisation)
+ Capable of model training and optimisation (for example, tuning hyper parameters, internal validation, optimal stopping)
+ Proficient in evaluating AI models using common metrics (for example, precision, recall, F1 score, Receiver Operator Characteristic analysis)

Governance

Regulation and standards

- Understanding of the different classes of medical device for AI software under UKCA and the related regulatory requirements
- Understanding of the limitations of CE/UKCA marking, particularly relating to performance and evaluation
- Capable of contributing to the appropriate processes for obtaining UKCA certification
- Capable of managing clinical governance processes required for AI software as a medical device (SaMD) including clinical audit, clinical risk management, quality assurance and clinical effectiveness

+ Proficient in applying GDPR (General Data Protection Regulation) to the creation and deployment of AI solutions
+ Proficient in applying NHS Digital Standards for clinical risk management (for example, DCB 0129 and DCB 1060)

Evaluation and validation

- Familiarity with evidence standards for AI products (for example, NICE evidence standards framework)
- Understanding of guidelines and governance for AI research projects and clinical trials
- Understanding of performance metrics for different AI algorithms and their interpretation, including limitations of common metrics

- Understanding of sources of possible error and bias resulting from AI model and validation design

+ Proficient in evaluating different types of AI algorithms and models

+ Proficient in designing and undertaking prospective clinical evaluation of AI products

+ Proficient in model bias assessment

Guidelines

+ Capable of following medical device development guidelines

Liability

- Familiarity with legal frameworks applying to the use of AI in clinical decision making. E.g. negligence, product liability

Implementation

Technical implementation

- Familiarity with the specific challenges associated with integrating AI into existing healthcare IT systems

- Familiarity with challenges in software integration and interoperability in a healthcare environment

+ Capable of applying principles of data governance in relation to AI deployment

Local validation

- Understanding of local validation methodology and interpretation

- Understanding of the concept of 'outlier cases' and how they may be identified

+ Capable of ascertaining circumstances in which additional local validation of AI technologies may be required

+ Capable of designing ongoing monitoring and evaluation of AI tools after their deployment

+ Capable of managing continued iteration and release of AI software
+ Proficient in defining scope of use and exclusion criteria for AI technologies

Systems impact

- Understanding of how to develop AI technologies to streamline existing workflows with seamless integration
- Understanding of how AI clinical workflow integration can impact clinical decision making and human cognitive biases

+ Capable of testing and evaluating the impact of an AI product workflow integration during product development
+ Proficient in establishing safety event reporting mechanisms

Clinical use

AI model and product design

- Familiarity with outlier detection and its confidence impact
- Understanding of the impact of using autonomous AI on adoption in terms of risk and confidence
- Understanding of the methods, benefits and limitations for model explainability in AI
- Understanding of the use of probability and certainty estimates in the presentation of AI predictions, and how these can impact clinician confidence

+ Capable of applying user-centred design and co-design principles
+ Capable of applying AI model transparency guidelines and standards for healthcare (for example, the Central Digital and Data Office's algorithmic transparency template[38] and model facts labels[39] or cards[40])

Cognitive biases

- Familiarity with different AI methods (for example, decision trees vs. deep learning) and their impact on clinician confidence
- from human errors in clinical reasoning and decision making (CRDM)
- Understanding the risks of cognitive biases in CRDM and how to mitigate these
- Understanding how CRDM context affects the tendency to automation, aversion, confirmation or rejection bias, and alert fatigue, regarding AI predictions

A.4 Advanced AI education for Embedders

Embedder

Implement, evaluate and monitor AI technologies deployed within healthcare settings

Example responsibilities

- Implement and integrate AI systems in healthcare settings
- Conduct technical implementation and systems integration
- Ensure that healthcare data used by AI technologies is managed safely and securely
- Establish and manage safety processes for reporting AI technology issues and back-up pathways for when products fail
- Conduct local validation of AI technologies if required
- Evaluate AI in terms of performance and clinical impact
- Participate in ongoing monitoring of AI technologies assessing for any model drift, including designing and performing algorithmic audits
- Design, deliver and continuously update product-specific user education, guiding users about how to use AI technologies safely and effectively

Examples of individuals who may take on this archetype role

- Specialist digital clinicians
- DDaT data professionals (data analysts, data engineers, data scientists)
- Clinical informatics professionals, including clinical scientists (such as clinical bioinformaticians)
- Statisticians

- Information technology (IT) teams
- Information governance (IG) teams
- Clinical Safety Officer (CSO) and clinical safety teams
- Knowledge Managers

Embedders are crucial in understanding and evaluating AI technologies in local settings, conducting local validation, monitoring and maintaining AI technologies and overseeing the systems change, workflow integration and staff training that will be necessary to deploy AI technologies.

Embedders will likely make up the majority of the AI multi-disciplinary teams (MDTs) discussed in detail in **section 4.1** They may include DDaT and clinical informatics professionals (data analysts, engineers, data scientists, and clinical scientists - including clinical bioinformaticians), specialist digital/AI clinicians, change management specialists, commercial strategy leads, amongst others.

Interviewees for this research noted that Embedders represent one of the least common archetypes in the current healthcare workforce. Strategies for training and resourcing growth for Embedder skills at a system-wide level are discussed in **section 4.2**.

Similar to Creators, it is not necessary for each individual Embedder to satisfy all advanced educational requirements. It is likely that AI teams will require different skills that depend on the nature of each project.

Table A5 lists the suggested advanced educational requirements for Embedders.

Table A5: Embedders: Requirements for advanced AI education

In addition to the knowledge requirements outlined in foundational AI education, Embedders will need the following more advanced knowledge and skills.

Taxonomy: • **Knowledge**
\+ **Skill**

AI literacy

• Familiarity with the data provenance, quality and structure requirements for developing AI models

• Familiarity with types of data-driven problems (for example, classification, regression, generative)

- Familiarity with types of algorithms, their benefits and limitations (for example, logistic regression, decision trees, support vector machines, random forest, K-means clustering, neural networks, Bayesian approaches)
- Familiarity with types of neural networks and their common variants (for example, fully connected network, convolutional neural network, recurrent neural network, generative adversarial network)
- Familiarity with types of learning methodology (for example, supervised, unsupervised, reinforcement learning, ensemble learning, distributed learning)
- Understanding of limitations of trained models, deriving from limitations of the available data sets

+ Capable of identifying appropriate types of algorithm to solve a given problem
+ Proficient in coding languages and tools used for the analysis of AI algorithms (for example, R, Python, Jupyter notebooks)
+ Proficient in validation methods (for example, hold out method, cross validation)
+ Proficient in interpreting metrics used for AI model evaluation (for example, precision, recall, F1 score, Receiver Operator Characteristic curve, Area Under Curve measures)

Governance

Regulation and standards

- Understanding of different classes of medical device for AI software under UKCA and the related regulatory requirements
- Understanding of the limitations of CE/UKCA marking, particularly relating to performance and evaluation
- Understanding of GDPR applied to healthcare AI products

+ Proficient in managing clinical governance processes required for AI software as a medical device (SaMD) including clinical audit, clinical risk management, quality assurance and clinical effectiveness
+ Proficient in applying NHS Digital Standards for clinical risk management (for example, DCB 0129 and DCB 1060)

Evaluation and validation

- Familiarity with evidence standards for AI products (for example, NICE evidence standards framework)
- Familiarity with guidelines and governance of AI research projects and clinical trials
- Understanding of performance metrics for different AI algorithms and their interpretation, including limitations of common metrics
- Understanding of sources of possible error and bias resulting from AI validation design

+ Capable of undertaking prospective clinical evaluation of AI products
+ Proficient in evaluating different types of AI algorithms
+ Proficient in identifying potential model bias and designing appropriate bias testing and mitigation
+ Proficient in designing and performing algorithmic audits and ongoing monitoring

Guidelines

- Awareness of AI medical device development guidelines

Liability

- Awareness of legal frameworks applying to the use of AI in clinical decision making (for example, negligence, product liability)

Implementation

Technical implementation

- Understanding of the challenges associated with integrating AI into existing healthcare IT systems

+ Proficient in software integration and interoperability in a healthcare setting
+ Proficient in applying principles of data governance in relation to AI product implementation

Local validation

+ Proficient in ascertaining circumstances in which additional local validation of AI technologies may be required
+ Proficient in conducting and interpreting local validation of AI technologies
+ Proficient in conducting ongoing monitoring and evaluation of AI technologies after their deployment
+ Proficient in defining the scope of use and exclusion criteria for AI technologies

Systems impact

+ Proficient in testing and evaluating the impact of AI technologies on clinical decisions and workflow integration during deployment
+ Proficient in establishing and managing internal and external processes for detecting, reporting, and managing adverse effects or serious incidents related to AI
+ Proficient in evaluating the impact of AI technology in terms of service efficiency, patient outcomes and workforce
+ Proficient in deploying AI technologies in a manner that streamlines existing workflows with effective systems integration

Clinical use

AI model and product design

- Awareness that key factors in product design (for example, transparency, level of detail, ease of user experience) can influence user confidence for AI in healthcare
- Familiarity with outlier detection methods and the impact of outliers on clinical confidence
- Familiarity with the methods, benefits and limitations of explainability in AI
- Understanding of the use of probability and certainty estimates in the presentation of AI predictions, and how these can impact clinician confidence

\+ Capable of applying AI model transparency guidelines and standards for healthcare

Cognitive biases

- Awareness of how a clinician's level of expertise in a given clinical area can influence their interpretation of AI information
- Awareness of how AI failure modes can differ from human error, and the significance for CRDM
- Familiarity with various types of algorithms, and the impact of algorithm type on trustworthiness and clinician confidence
- Understanding cognitive biases, their risks, and approaches to mitigate these

\+ Proficient at evaluating published AI performance metrics and evaluation data and communicating their real-world relevance to clinicians

As part of their responsibilities, Embedders will need to appraise AI technologies to determine whether they have met appropriate governance standards and display acceptable performance for the clinical scenario, to assess the requirements for their implementation and to ascertain the potential impact on patient outcomes and clinical workflows.

Table A6 lists the questions that Embedders will need answered to develop confidence in the suitability of a specific AI technology.

Table A6: Embedders: Questions to establish confidence in specific AI technologies

Governance

Regulation and standards

- What are the clinical safety processes for detecting, reporting, and managing serious incidents due to software errors?
- Is the AI technology a medical device according to UK regulation? If so, does it have appropriate UKCA/CE marking? What class of medical device has it been designated and is this appropriate?
- What is the manufacturer's intended use of the product? (including any exclusions or limitations of scope)
- Is it compliant with NHS digital standards (for example, DCB 0129, DCB 0160)?
- Is it compliant with appropriate ISO standards (for example, ISO 82304, ISO 13485)?
- What are the limits of regulation for this product and is local evaluation required to fill the gaps?

Evaluation and validation

- What are the specific risks of bias in AI model design and training for this technology?
- What steps have been taken to mitigate against these biases? How can they be further mitigated during implementation and local validation?
- What are the limitations in how the AI technology was designed, trained and validated?

Implementation

Technical implementation

- What are the technical requirements for the AI technology? Will the technology integrate with existing IT systems or does it need development of new systems?
- What are the requirements for data generation, recording, curation, processing, dissemination, sharing, and use?
- What IP arrangements are needed?
- What are the risks for data security and privacy? What arrangements are needed for data protection and privacy?
- What arrangements are needed for the ongoing technical maintenance and updates of the AI technology?

Local validation

- Does the published validation cohort for this AI technology represent the local clinical population sufficiently well to be transferrable?
- Is local validation and/or other actions (for example, change in scope of use) needed to address the AI technology's limitations?
- If required how could local validation be conducted for this AI technology?
- What level of ongoing model surveillance is appropriate for safety and maintenance of the AI technology's rigour?
- How can we develop a robust performance monitoring plan?
- What levels of staff support and infrastructure are needed for the ongoing technical maintenance and updates of the AI technology?

Systems impact

- How will the AI technology affect the current workflows and pathways (clinical and administrative)? Is broader redesign needed to take advantage of the technology?
- How should we set up backup workflow if the AI technology fails?

- How best to ensure clinical safety in the local deployment of AI technologies?
- What processes do we need to review and respond to relevant safety recommendations and alerts?
- How can we ensure fairness, transparency and equitable outcomes in the use of AI technologies?

A.5 Advanced AI education for Users

User

Use AI technologies within healthcare settings

Example responsibilities

- Use AI within healthcare settings in accordance with guidelines
- Employ appropriate safety measures related to the use of AI
- Communicate with patients and the public about AI

Examples of individuals who may take on this archetype role

- Clinicians using AI
- Non-clinical staff using AI
- Clinical researchers using AI

Interviewees for this research noted the need for advanced education for Users will depend on their specific responsibilities and the risks associated with using the AI technology. For example, administrative staff using an AI technology to automate appointment bookings will not require the same detailed knowledge of AI as a clinician using an AI technology to assist in high-stakes clinical decision making.

All Users will require product-specific training to educate them on how to use AI technologies safely and effectively as detailed in **section 3.4**.

Using AI for clinical reasoning and decision making (CRDM)

Interviewees for this research highlighted the need to provide clinicians with the knowledge and skills they require to use AI as these technologies become increasingly rolled out in healthcare settings.

As discussed in the **first report**[1], clinicians vary in their attitudes towards technology and change, which can dictate their willingness to use AI in their work. However, it is important that AI and CRDM-related education reaches all clinicians to optimise patient care throughout all settings and minimise any disparities in how AI technologies are adopted and used.

Ideally, CRDM-related education for clinician Users will be tailored to specific clinical roles, levels of seniority and speciality. This education should reach clinicians in training as well as those who are fully qualified. Education should be directed to all professionally trained clinical staff including doctors, nurses, pharmacists and allied healthcare professionals (AHPs).

Clinician Users will require advanced knowledge of the impact of AI in CRDM to ensure that AI technologies are being used in a fair, robust and safe manner. This should include an understanding of the limitations and weaknesses of machine learning algorithms, and situations in which they are most likely to underperform or erroneous results. It should also include an awareness of the potential impact of using AI technologies on decision making, including the influence of human cognitive biases and the risks of over and under confidence in AI.

Communication skills to enable discussion with patients and caregivers about AI technologies should form an important part of clinician User education. Broad adoption of AI technologies has the potential to reshape the relationships between clinicians and patients, requiring clear communication and soft skills to help counsel patients about the use of AI technologies and guide shared clinician-patient care decisions. Clinician Users will need to know how to advise patients about the ownership and sharing of their personal data, and be able to discuss the implications of using AI technologies on their personal data and care.

Some Users may undertake additional education and training to become specialist digital/AI clinicians with a mixture of clinical and technical skills and may end up taking on additional Embedder and/or Creator roles. This is discussed further in **section 4.2**.

Table A7 lists the suggested advanced educational requirements for Users.

Table A7: Users: Requirements for advanced AI education

In addition to the knowledge requirements outlined in foundational AI education, Users will need the following more advanced knowledge and skills.

Taxonomy: • **Knowledge** + **Skill**

Governance

Evaluation and validation

- • Familiarity with the limitations of CE/UKCA marking, relating to performance and evaluation.
- • Familiarity with evidence standards for AI products (for example, NICE evidence standards framework)
- • Familiarity with guidelines and governance for AI research projects and clinical trials
- • Understanding of performance metrics for different AI algorithms and their interpretation, including limitations of common metrics
- • Understanding of sources of possible error and bias resulting from AI model and validation design
- + Capable of critically appraising published evidence for the performance of an AI algorithm in their area of practice

Guidelines

- • Familiarity with clinical guidelines relating to use of AI in their area of practice

Liability

- • Familiarity with legal frameworks applying to the use of AI in clinical decision making. E.g. negligence, product liability

Clinical use

AI model and product design

- Familiarity with different ways in which bias in AI algorithms may occur and the potential impact on clinical decision making
- Understanding of the methods, benefits and limitations for model explainability in AI
- Understanding of the role of AI model explainability in clinical confidence, including limitations of some explainability approaches for confidence in predictions for specific patients

Cognitive biases

- Awareness of where to seek guidance on the use of AI technologies in complex clinical scenarios
- Familiarity with of potential AI failure modes, how these may differ from human error and how to report AI safety incidents
- Understanding of how and why some clinicians may be under- or over-confident in information derived from AI technology
- Understanding the effect of clinical domain expertise on being under- or over-confident in information derived from AI technology
- Understanding AI performance metrics and how to interpret published research relating to AI technologies
- Understanding of 'appropriate confidence' in relation to CRDM, including the fact that the optimal confidence level may vary from case to case
- Understanding how information derived from AI may differ from other information used in CRDM and what this means for making clinical decisions
- Understanding the risks of cognitive biases in CRDM and approaches to mitigate against these
- Understanding how CRDM context (time criticality, patient involvement, clinical risk) and workflow integration affect the tendency to accept or reject AI-derived information

- Capable of balancing the risks and benefits of AI-assistance in CRDM for a given clinical task
- Capable of identifying instances in which it is, and is not, appropriate to use a specific AI technology for decision support
- Proficient in how to address disagreement between clinical intuition and information derived from AI technologies

Interface with patients

- Capable of discussing issues relating to data privacy and data use with patients in relation to AI technologies
- Proficient in communicating how AI-derived information has been incorporated in clinical decision making alongside other clinical information
- Proficient in counselling patients about the benefits and risks of AI technologies and their impact on shared clinical decision making

Appendix B: List of interviewees

Following is a list of individuals interviewed for this research who have agreed to be acknowledged. The report outlines a synthesis of a range of insights and opinions, and as such, responsibility for the content of the report rests with the authors.

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Dr Luke Nicholson
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Consultant Ophthalmic Surgeon

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Healthy.io
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University of Cambridge
Chair, Winton Centre for Risk and Evidence Communication

Harini Suresh
MIT
PhD candidate in Electrical Engineering and Computer Science

Mark Swindells
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Assistant Director - Standards and Ethics

Dr Jay Verma
Shakespeare Health Centre
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